Lake Michigan Shoreline TMDL for *E. Coli* Bacteria

Data Report

Submitted to:
Indiana Department of Environmental Management
100 N. Senate Avenue
P.O. Box 6015
Indianapolis, IN 46206

Submitted by:
Tetra Tech, Inc.
Water Resources and TMDL Center

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1.0 INTRODUCTION

Indiana's portion of the Lake Michigan shoreline (Figure 1) encompasses 43 miles of the lake's total shoreline length (1,638 miles). It includes the Indiana Dunes National Lakeshore and many beaches that are used extensively by residents throughout the Midwest. The shoreline appears on Indiana's section 303(d) list of impaired waters for failing to fully support its swimmable designated use due to an *Escherichia Coli* (*E. Coli*) impairment (Table 1)[1]. The *E. Coli* impairment was identified based on data collected by the Indiana Department of Environmental Management (IDEM) and other agencies during water quality surveys which showed violations of the standard. *E. Coli* is a bacterium that indicates the presence of human sewage and animal manure. It can enter water bodies through direct discharge from mammals and birds, from agricultural and storm runoff carrying mammal wastes (manure), and from sewage leaked into the water. *E. Coli* is also an indication of the possible presence of other disease causing organisms or pathogens. Violations of the standard resulted in an average of more than 15 beach closures per year at the National Lakeshore and state park during the period 1990 to 2000 (Luther, 2001) with associated recreational and economic costs.

Table 1. Listing information for Lake Michigan from the Indiana 1998 section 303(d) list

Water Body	Designated Use	Support Status	Parameters of Concern
Lake Michigan	Aquatic Life Use	Full Support	--
	Swimmable	Partial Support	***E. Coli***

Sources: IDEM, 1998a; IDEM, 1998b.

The Clean Water Act and U.S. Environmental Protection Agency (USEPA) regulations require that states develop Total Maximum Daily Loads (TMDLs) for all waters on the section 303(d) lists. A TMDL is the sum of the allowable amount of a single pollutant that a waterbody can receive from all contributing point and nonpoint sources and still support its designated uses. In addition to the Lake Michigan shoreline, several stream segments located within the Lake Michigan basin are listed on Indiana's section 303(d) list and require TMDLs (Figure 2). This report presents the results of initial data collection efforts for developing *E. Coli* TMDLs specifically for the shoreline. TMDLs associated with impaired stream segments within the Lake Michigan basin are not addressed here. The overall goals and objectives of the Lake Michigan shoreline TMDL are to

- Assess the water quality of Lake Michigan and identify key issues associated with the impairments and potential pollutant sources.
- Use the best available science to determine the maximum load of *E. Coli* that the shoreline can receive and still fully support all of its designated uses.
- Use the best available science to determine current loads of *E. Coli*
- If current loads exceed the maximum allowable load, determine the load reduction that is needed.
- Identify feasible and cost-effective actions that can be taken to reduce loads
- Inform and involve the public throughout the project to ensure that key concerns are addressed and the best available information is used
- Submit a final TMDL report to USEPA for review and approval

[1] Indiana's current section 303(d) list is the one submitted to and approved by USEPA in 1998. A draft 2002 section 303(d) list is currently being reviewed by USEPA.

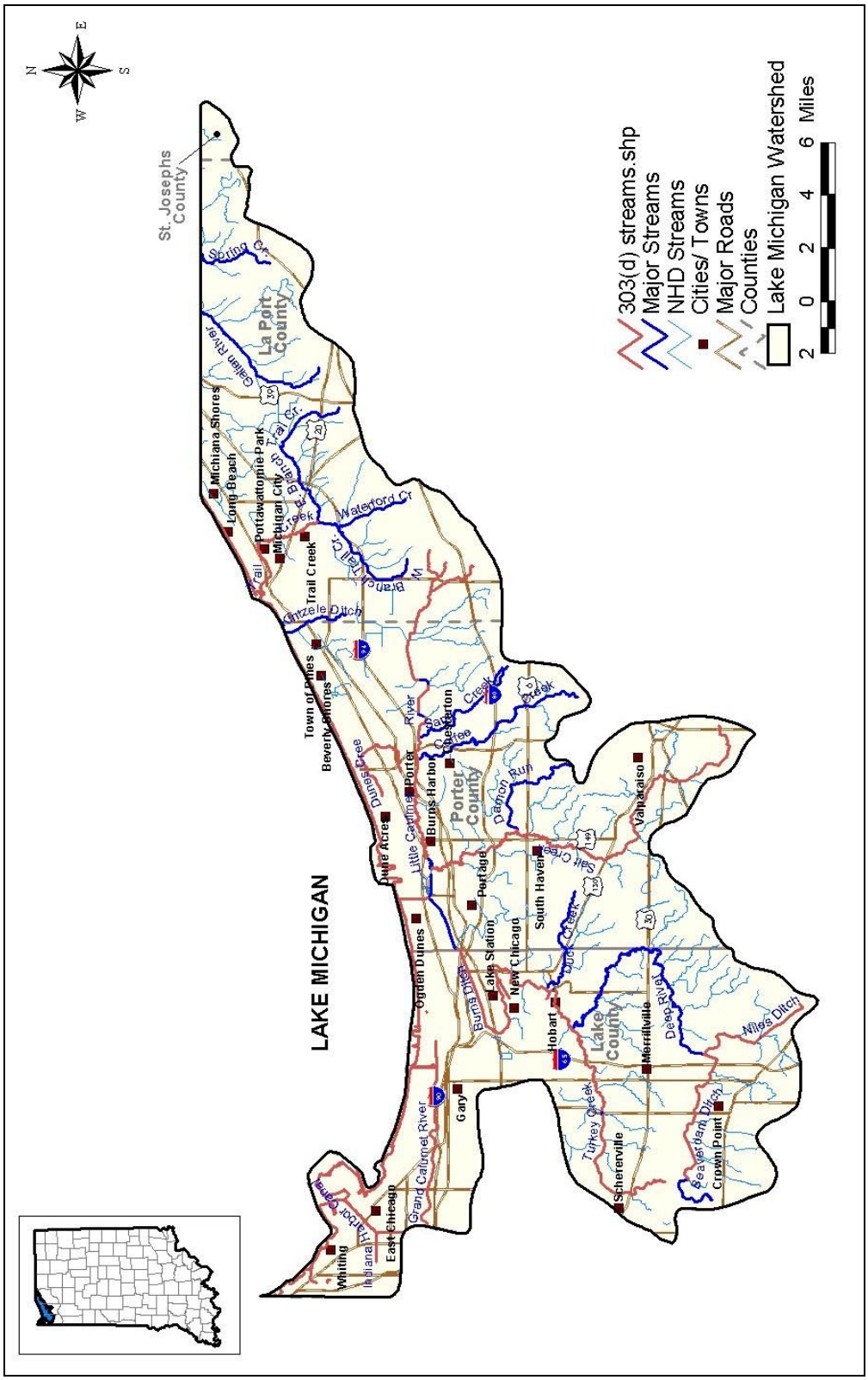

Figure 1. Political map of the Lake Michigan watershed.

This report provides an inventory of available information collected to date that will be used during the development of the TMDL, describes the physical setting of the watershed, and discusses the spatial and temporal extent of *E. Coli* concentrations. The report contains a discussion of the following topics:

- Population
- Topography
- Land Uses
- Lakeshore Characteristics
- Climate and Weather
- Water Quality

One of the main purposes of the report is to solicit additional information on these and other relevant topics. The shoreline has been extensively studied over the years and we intend to build off this previous work, to the extent possible, in developing the TMDL. Future reports will further identify and assess the sources of *E. Coli*, recommend a modeling approach, present the regulatory elements of the TMDL and identify implementation activities.

2.0 WATERSHED CHARACTERISTICS

The Lake Michigan shoreline covers 43 miles of Indiana's northwestern border (Figure 1). The watershed associated with the shoreline is part of the Little Calumet-Galien U.S. Geological Survey (USGS) cataloging unit (HUC 4040001). This watershed covers 536 square miles and encompasses portions of Lake, Porter, and LaPorte counties. The following sections provide information on the population, land uses, topography, and climate associated with the watershed. Obtaining an understanding of these issues is a critical first step in developing a TMDL because they provide information on the potential sources of *E. Coli*, as well as characteristics of the watershed that might affect water quality.

2.1 Population

The population of the Lake Michigan watershed is estimated to be approximately 540,000 with the majority of people concentrated in the cities of Gary, Hammond, East Chicago and Michigan City (Table 2). The population estimate is based on data from the 2000 U.S. Census Bureau and the use of a geographic information system (GIS) to estimate populations outside of incorporated cities and towns. Several cities in the watershed experienced declining populations between 1990 and 2000. However, the populations of St. John (Lake County) and Porter (Porter County) increased significantly during this same time period. The major population center in the watershed is Gary, an industrial city with a population of approximately 116,646 people (US Census Bureau, 2000).

Table 2. Population data for cities within the Lake Michigan watershed[2].

City/Town	County	1990 Population	2000 Population	Percent Change
Long Beach	La Porte	2,044	1,559	-23.73
Michigan City	La Porte	33,822	32,900	-2.73
Trail Creek	La Porte	2,463	2,296	-6.78
Westville	La Porte	5,255	2,116	-59.73
Cedar Lake	Lake	8,885	9,279	4.43
Crown Point	Lake	17,728	19,806	11.72
East Chicago	Lake	33,892	32,414	-4.36
Gary	Lake	116,646	102,746	-11.92
Griffith	Lake	17,916	17,334	-3.25
Hammond	Lake	84,236	83,048	-1.41
Hobart	Lake	21,822	25,363	16.23
Lake Station	Lake	13,899	13,948	0.35
Merrillville	Lake	27,257	30,560	12.12
New Chicago	Lake	2,066	2,063	-0.15
Schererville	Lake	19,926	24,851	24.72
St. John	Lake	4,921	8,382	70.33
Whiting	Lake	5,155	5,137	-0.35
Winfield	Lake	NA	2,298	Unknown
Beverly Shores	Porter	622	708	13.83
Burns Harbor	Porter	788	766	-2.79
Chesterton	Porter	9,124	10,488	14.95

City/Town	County	1990 Population	2000 Population	Percent Change
Dune Acres	Porter	263	213	-19.01
Lakes of the Four Seasons	Porter	6,556	7,291	11.21
Ogden Dunes	Porter	1,499	1,313	-12.41
Portage	Porter	29,060	33,496	15.26
Porter	Porter	3,118	4,972	59.46
South Haven	Porter	6,112	5,619	-8.07
Town of Pines	Porter	789	798	1.14
Valparaiso	Porter	24,414	27,428	12.35
Total Population in Cities/Towns		**500,278**	**509,192**	**1.78**
Estimated Population Outside of Cities/Towns (area weighted estimate based on county populations)		**42,825**	**47,778**	**11.57**
Total Watershed Population		**543,103**	**556,970**	**2.55**

[2]Note that portions of some cities are outside the watershed.

2.2 Topography

The Lake Michigan watershed lies in the Calumet Lacustrine Plain, a physiographic region characterized by relatively high relief throughout. Topography in the watershed is a result of moraine formation by active ice and by the overspreading of the region with ablation or flow till that formed during times of glacial retreat. Figure 2 presents the general topography within the Lake Michigan watershed. Elevation ranges from 577 feet at the shoreline to 900 feet in the headwaters (USGS, 1993).

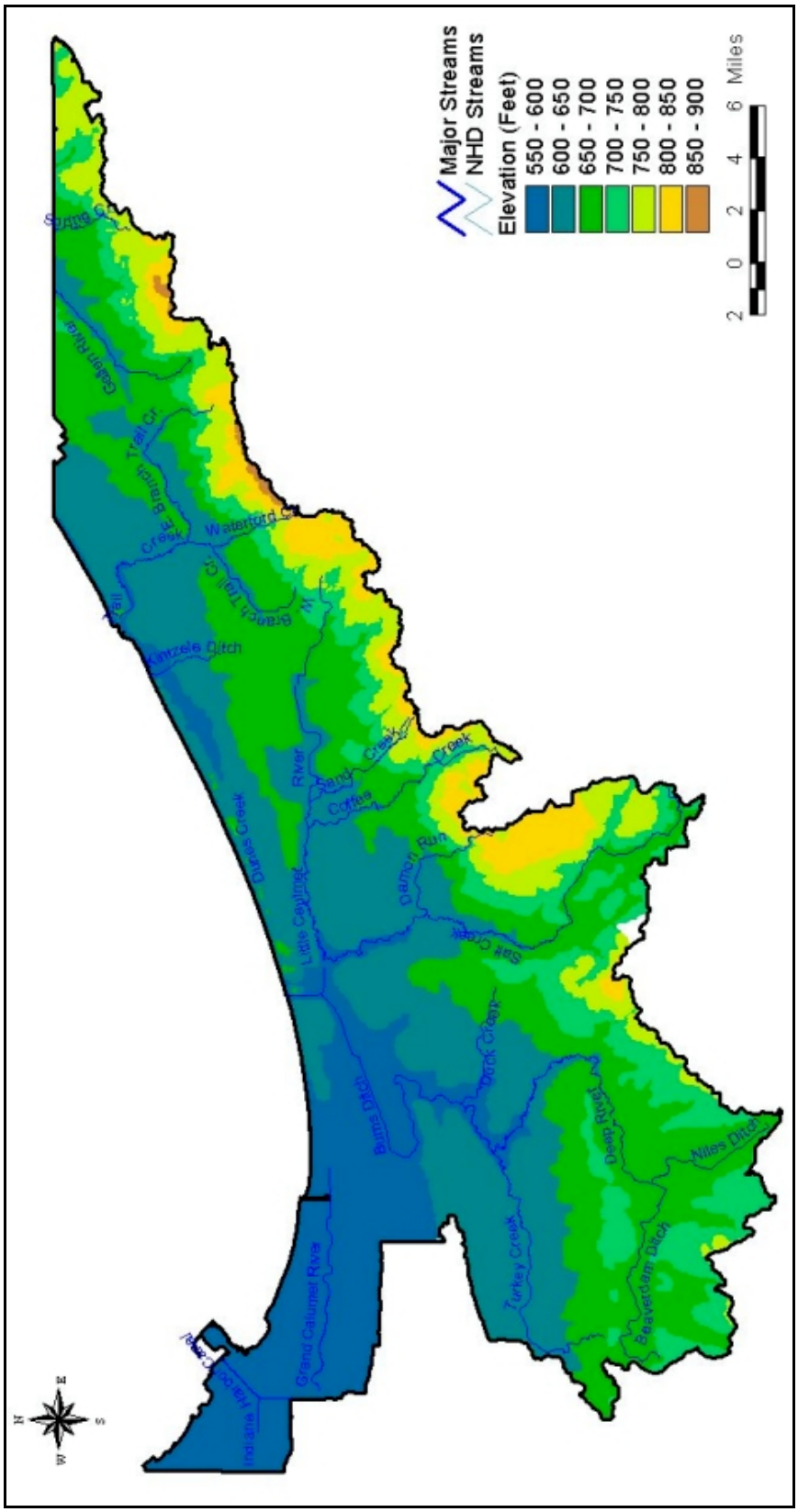

Figure 2. Topography of the Lake Michigan watershed.

2.3 Land Use

Land use information for the Lake Michigan watershed is available from the Multi-Resolution Land Characteristics Consortium (MRLC). The following federal agencies formed the MRLC to order to acquire satellite-based remotely sensed data for their environmental monitoring programs: U.S. Geological Survey, Environmental Protection Agency, National Oceanic and Atmospheric Administration, Forest Service, National Atmospheric and Space Administration, and the Bureau of Land Management. The land use data are derived from images acquired by Landsat's Thematic Mapper satellite during the early 1990s. These data categorize the land use for each 100 foot by 100 foot parcel of land in the watershed.

Table 3 provides a breakdown of the land uses in the watershed and Figure 3 displays the spatial distribution of the land uses. The watershed is mostly row crop agriculture with areas of high density residential lands. It should be pointed out that since the MRLC data are based on satellite imagery from the early 1990s, land uses in some parts of the watershed may have changed. Estimates of the extent of such change will be made using the population data presented above and the recommendations of local government officials. These updated estimates will be used for development of the TMDL.

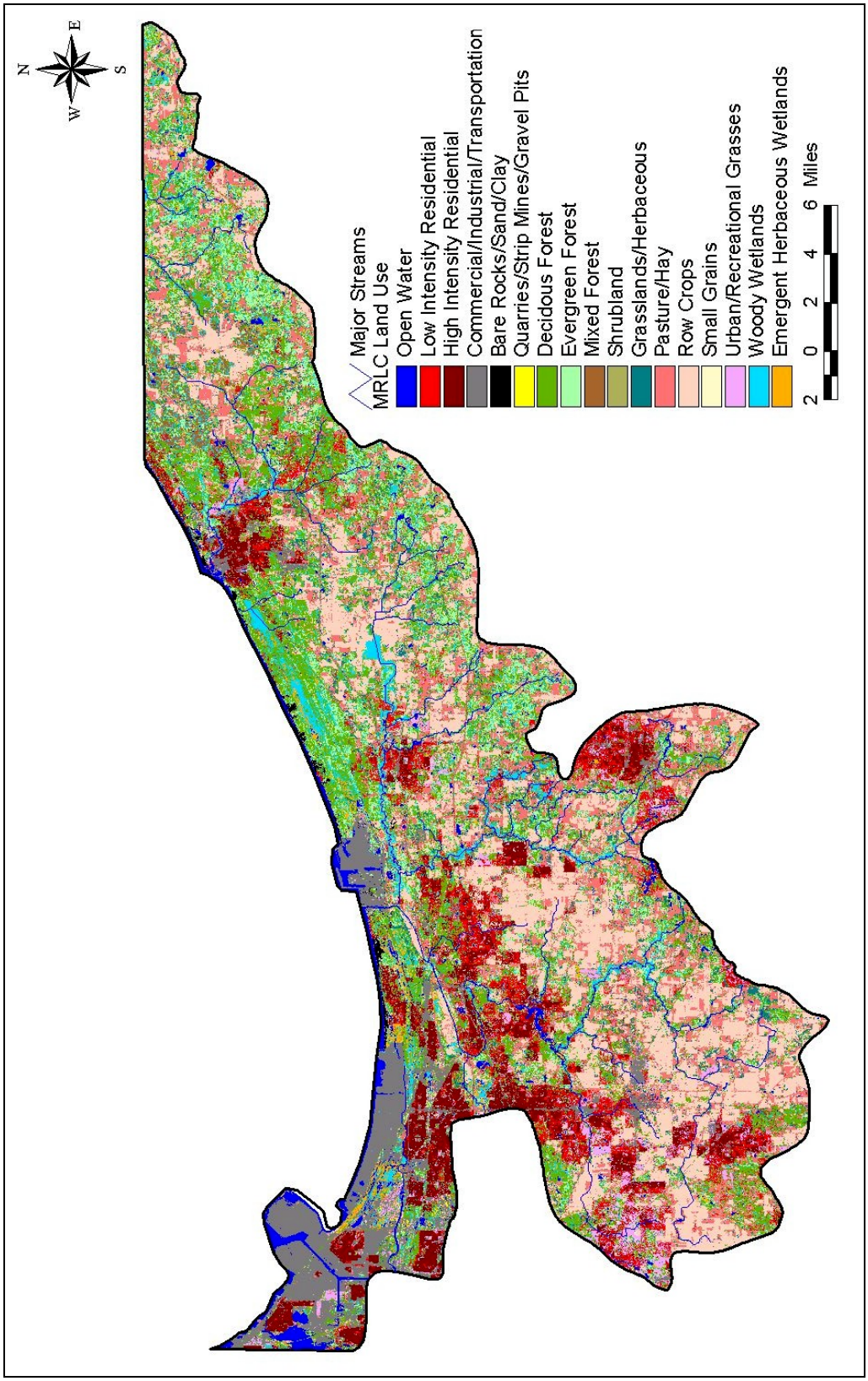

Figure 3. Land use in the Lake Michigan watershed.

Table 3. Land use distribution in the Lake Michigan watershed

Land Use	Area (acres)	Percent (%)
Row Crops	79,447	22.08
Deciduous Forest	65,175	18.11
Pasture/Hay	44,997	12.51
Commercial/Industrial/Transportation	29,026	8.07
Evergreen Forest	25,529	7.10
High Intensity Residential	22,908	6.37
Low Intensity Residential	22,274	6.19
Woody Wetlands	20,274	5.63
Grasslands/Herbaceous	15,042	4.18
Open Water	10,968	3.05
Urban/Recreational Grasses	10,771	2.99
Emergent Herbaceous Wetlands	8,374	2.33
Mixed Forest	2,953	0.82
Bare Rock/Sand/Clay	1,029	0.29
Shrubland	540	0.15
Small Grains	206	0.06
Undefined	185	0.05
Quarries/Strip Mines/Gravel Pits	102	0.03
Total	359,800	100.00

Source: MRLC, 2000.

3.0 LAKE AND LAKESHORE CHARACTERISTICS

Lake Michigan is the third largest Great Lake by surface area and the sixth largest freshwater lake in the world. General characteristics of the entire lake are presented in Table 4. The following coordinates define the Indiana portion of the Lake Michigan: 41° 45' 42N latitude North, 87° 31' 29'' longitude West and 86° 49' 18" longitude East. Using these coordinates, the characteristics of the lake within Indiana were calculated and are presented in Table 5.

Table 4. General characteristics of the Lake Michigan shoreline in Indiana.

LAKE MICHIGAN		INDIANA'S PORTION OF LAKE MICHIGAN	
Characteristic	**Value**	**Characteristic**	**Value**
Length	307 miles	Greatest Length	10 miles
Breadth	118 miles	Greatest Width	36 miles
Average Depth	279 ft.	Average Depth	155 ft.
Maximum Depth	925 ft.	Maximum Depth	249 ft.
Volume	1,180 cubic miles	Volume	6.754 cubic miles
Water Surface Area	22,300 sq. miles	Water Surface Area	226 sq. miles
Drainage Basin Area	45,600 sq. miles	Drainage Basin Area	536 sq. miles
Elevation	577 ft.	Elevation	577 ft.
Retention Time:	99 years	Retention Time	Unknown

3.1 Indiana Dunes National Lakeshore

A significant portion of the Indiana Lake Michigan shoreline was designated as the Indiana Dunes National Lakeshore in 1966. The National Lakeshore runs for nearly 25 miles along southern Lake Michigan, bordered by Michigan City, Indiana on the east, and Gary on the west. The park contains approximately 15,000 acres, 2,182 of which are located in Indiana Dunes State Park and managed by the Indiana Department of Natural Resources. The National Lakeshore contains miles of beaches, sand dunes, bog, wetlands and woodland forests. Figure 4 presents the location of several beaches on the shoreline, including those that are part of the Indiana Dunes National Lakeshore.

3.2 Bathymetry

The measurement of depths of water in a lake is known as its bathymetry. The bathymetry of Lake Michigan is available through several sources, including the National Oceanic and Atmospheric Administration's (NOAA's) National Environmental, Satellite and Data and Information Service. The bathymetry map presented in Figure 5 is limited to the Indiana portion of Lake Michigan as defined by its political boundaries. It shows that lake depths along the shoreline typically range from 0 to 25 feet.

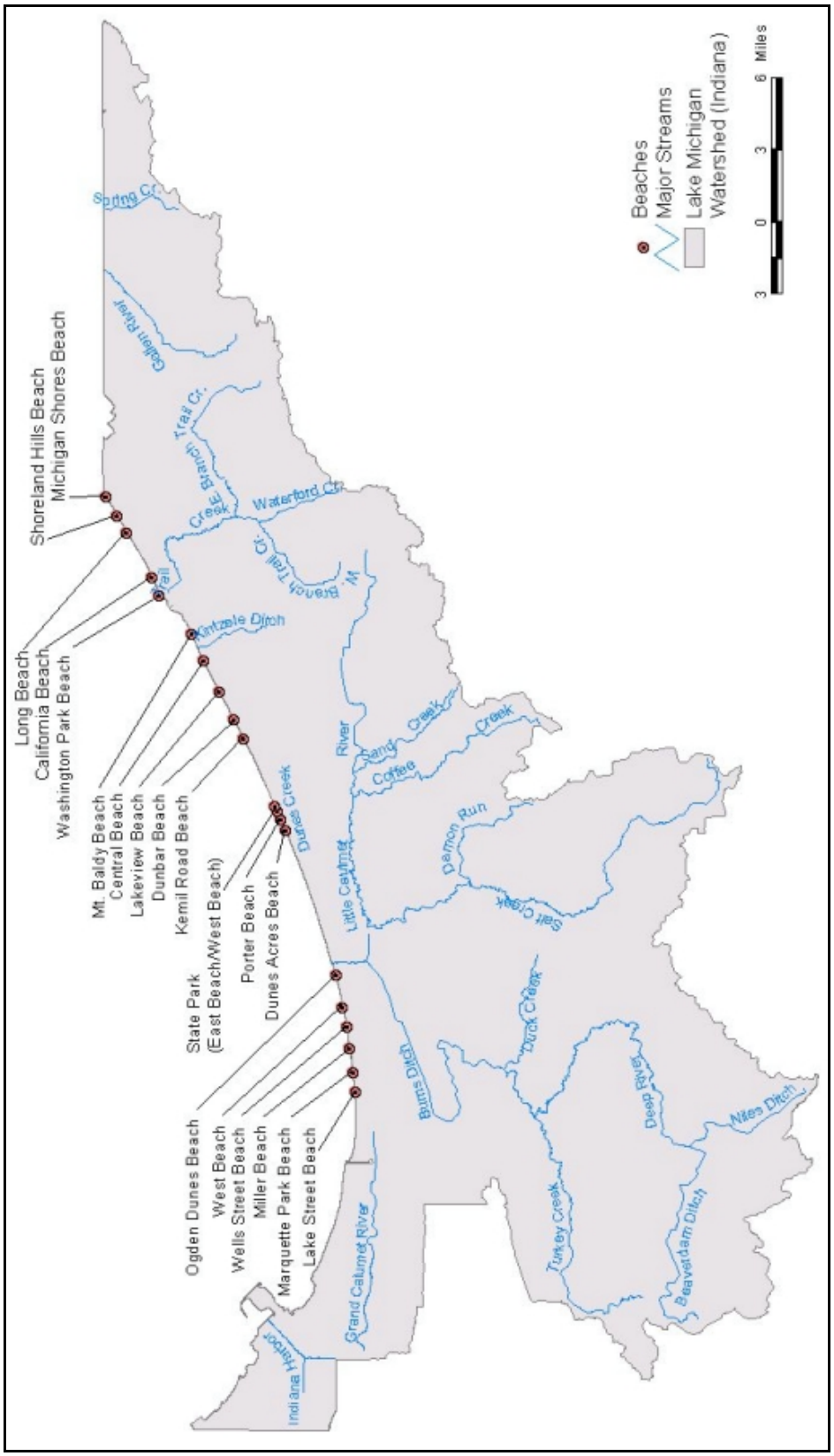

Figure 4 Location of beaches on Indiana Lake Michigan Shoreline

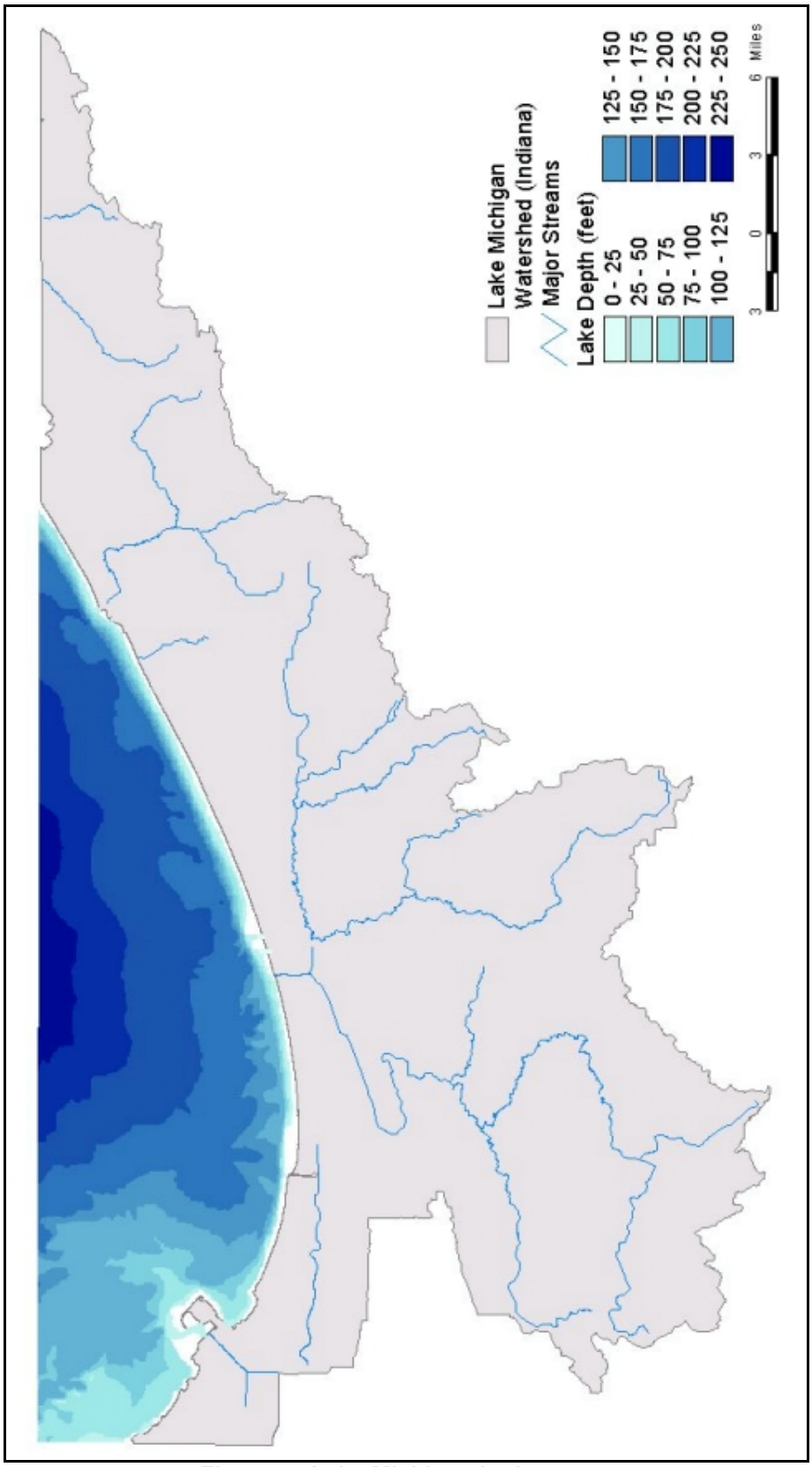

Figure 5. Lake Michigan bathymetry.

3.3 Coastal Dynamics

Lake Michigan's waves and currents are the result of winds traveling across the length of the lake. Intense storms produce waves and currents which move large quantities of sand along the beach and lake bottom. The most powerful storm waves approach Indiana's coast from the north. The strongest storm winds blow out of the northwest, north, and northeast directions. These winds are able to transfer considerable energy into waves coming from the north because there is approximately 300 miles of open water between the north end of Lake Michigan and the Indiana coastline. The shoreline east of Gary is oriented in a northeast by southwest direction. The shoreline west of Gary is oriented in a northwest by southeast direction. As storm waves approach from the north, the different orientation of the shorelines results in both currents flowing toward Gary.

Data available from the U.S. Army Corps of Engineers and NOAA will be collected and used to describe the wave and current patterns within the lake and assess how they impact *E. Coli* concentrations. This information will be presented in the modeling report.

4.0 CLIMATE AND HYDROLOGY

4.1 Climate

The Lake Michigan watershed has a climate characterized by warm summers and cool winters. Average annual temperatures can range from 40.5 degrees to 59.0 degrees Fahrenheit. Several National Climatic Data Center (NCDC) gages are located in or near the watershed. These stations record climatic variables such as temperature, precipitation, wind speed and potential evapotranspiration. The stations nearest the lakeshore are at the Gary Buffington Harbor (Coop ID: 123208), Indiana Dunes National Lakeshore (Coop ID 124244) and Michigan City (ICS ID 18c). Several additional stations within the watershed record precipitation and temperature only. Figure 6 shows the locations of these climate and precipitation stations.

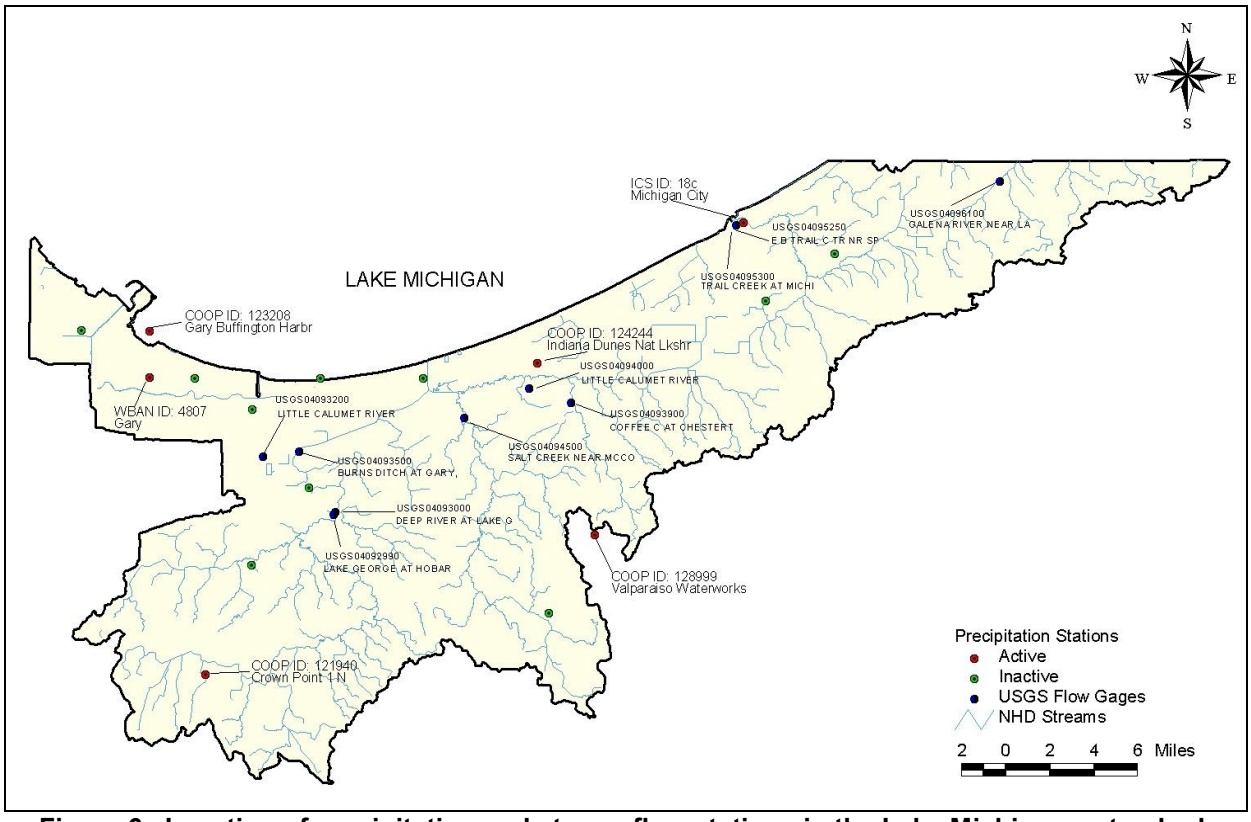

Figure 6. Location of precipitation and stream flow stations in the Lake Michigan watershed.

Historical data from the Indiana Dunes National Lakeshore station were used to characterize the precipitation patterns along the shore. During a 29 year period between 1971 and 2000, the average annual precipitation recorded at the station was 37.86 inches. The minimum average annual precipitation was 30.5 inches in 1999 and the maximum was 61.3 inches in 1990. The mean annual number of days when precipitation exceeds 0.10 inch is about 76 days. Figure 7 presents the monthly average precipitation for this period.

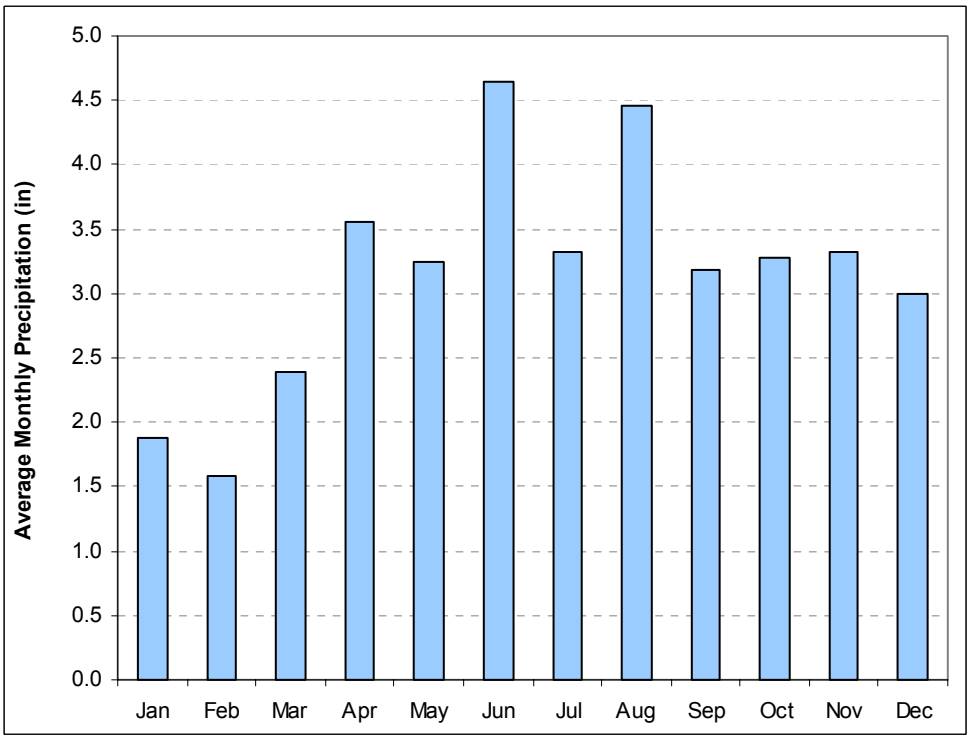

Figure 7. Monthly average precipitation at Indiana Dunes National Lakeshore station (1971-2000).

4.2 Hydrology

Ever since the last glaciers retreated about 10,000 years ago, Lake Michigan's water levels and outflows have been fluctuating, affecting the lakeshore environment and human activities. The major influences on Great Lakes hydrology are weather and climate, which affect the balance of water in the Great Lakes and their connecting channels. Water enters the system as precipitation, runoff from the surrounding land, streamflow, direct point source discharges and groundwater inflow. Water leaving the system consists of evaporation from the water's surface, groundwater outflow, consumptive uses and diversions.

Several rivers and streams flow into Lake Michigan, and the major tributaries are the Fox-Wolf, the Grand and the Kalamazoo. There is a diversion from the lake into the Mississippi River basin through the Illinois Waterway at the Chicago River. Lake Michigan's cul-de-sac formation means that water entering the lake circulates slowly and remains for a long time (retention time is approximately 99 years) before it leaves the basin through the Straits of Mackinac (Great Lakes Information Network, 2002).

The present hydrology of the Lake Michigan coastal area in Indiana is significantly changed from what existed prior to human development. The industrialization and urbanization which began in northwest Indiana during the late nineteenth century altered the natural landscape and the natural drainage patterns. Many man-made lakes ponds and excavations remain in place of marshes, swamps, and wetlands. Tributaries to the Lake Michigan Basin in Indiana include the Calumet River, the Grand Calumet River, Trail Creek, Indiana Harbor Canal, the Portage-Burns Waterway and several smaller tributaries and man-made ditches. In addition, several industrial facilities are permitted to discharge directly into Lake Michigan (Table 6) and constitute another input in the water balance of the lake.

Table 5. Facilities with NPDES permits to discharge into Lake Michigan.

ID	Facility	Receiving Water	Flow Rate (mgd)
IN0000221	Commonwealth Edison Company Hammond	Lake Michigan	554
IN0029793	Lehigh Portland Cement/Gary	Lake Michigan	NA
IN0000132	NIPSCO, Bailey Generating Station	Lake Michigan	NA
IN0000035	Praxair Inc., Lakeside Plant (Gary)	Lake Michigan	NA
IN0000108	American Oil Company, Whiting	Lake Michigan	NA
IN0000116	NIPSCO, Michigan City Generating Station	Lake Michigan	240.7
IN0035793	Shady Oaks Mobile Home Park	Lake Michigan	0.022
IL0001996	Chicago-Jardine Water Purification Plant	Lake Michigan	NA

Lake levels for Lake Michigan have been recorded since 1960 at Calumet Harbor in Illinois and are monitored by the U.S. Army Corps of Engineers. Lake level information can also be obtained from the National Oceanic and Atmospheric Administration. Figure 8 presents the fluctuation of lake levels over a ten year period (1991-2001).

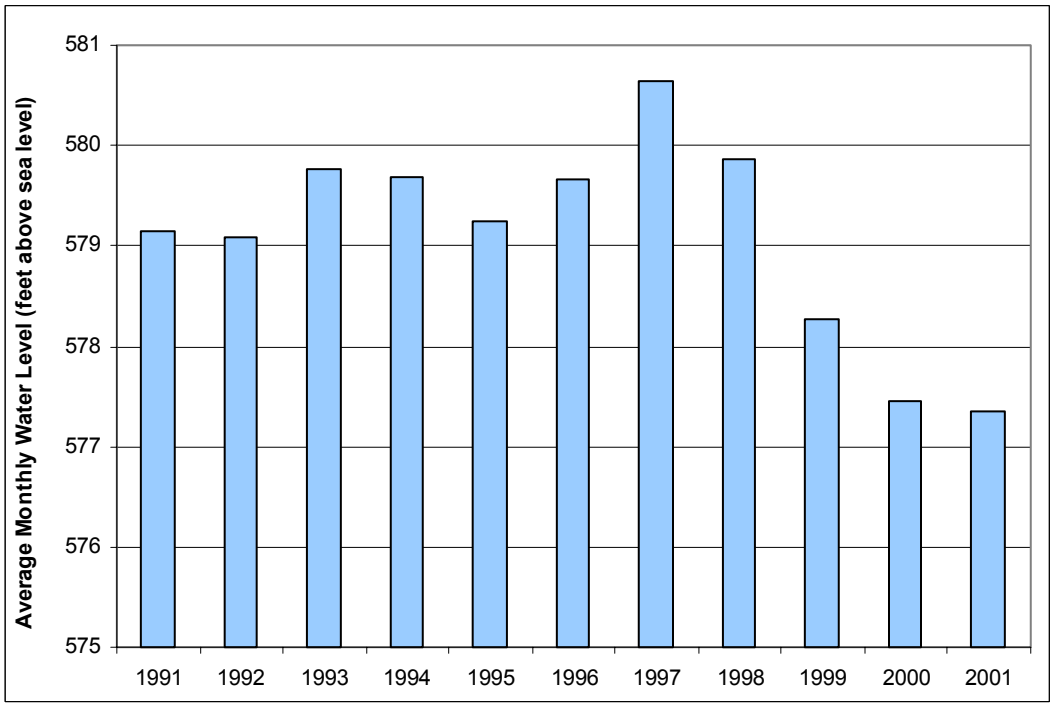

Figure 8. Lake levels at Calumet Harbor, Illinois (1991-2001)

5.0 INVENTORY AND ASSESSMENT OF WATER QUALITY INFORMATION

IDEM monitors the presence of *E. Coli* under the Surface Water Quality Assessment program. The impairment assessment for the lakeshore was made using data collected by IDEM as well as those collected by other organizations, primarily the Interagency *E. Coli* Taskforce. IDEM has sampled water quality data for 89 monitoring stations in the Lake Michigan watershed. Most of these are located on tributaries with 6 stations being in Lake Michigan. The Interagency *E. Coli* Taskforce has 28 water quality stations in the watershed and most of these, 24, are on the shoreline. Combining all the data results in 30 stations on the lakeshore out of a total of 117 stations. The total number of *E. Coli* records is 8,396 and the data spans the period between May 1984 and July 2002. Relevant statistics of *E. Coli* data for all stations are presented in Appendix A and B. In addition several other relevant parameters have been sampled, including pH, total suspended solids and temperature. Figure 9 presents the locations of surface water quality stations in the watershed, including the shoreline stations.

IDEM has identified the entire shoreline of Indiana's portion of Lake Michigan as impaired and listed on Indiana's 1998 section 303(d) list for violations of the *E. Coli* water quality standards. The sections below present the results of a spatial and temporal analysis of the data to verify and better understand the nature of the impairment.

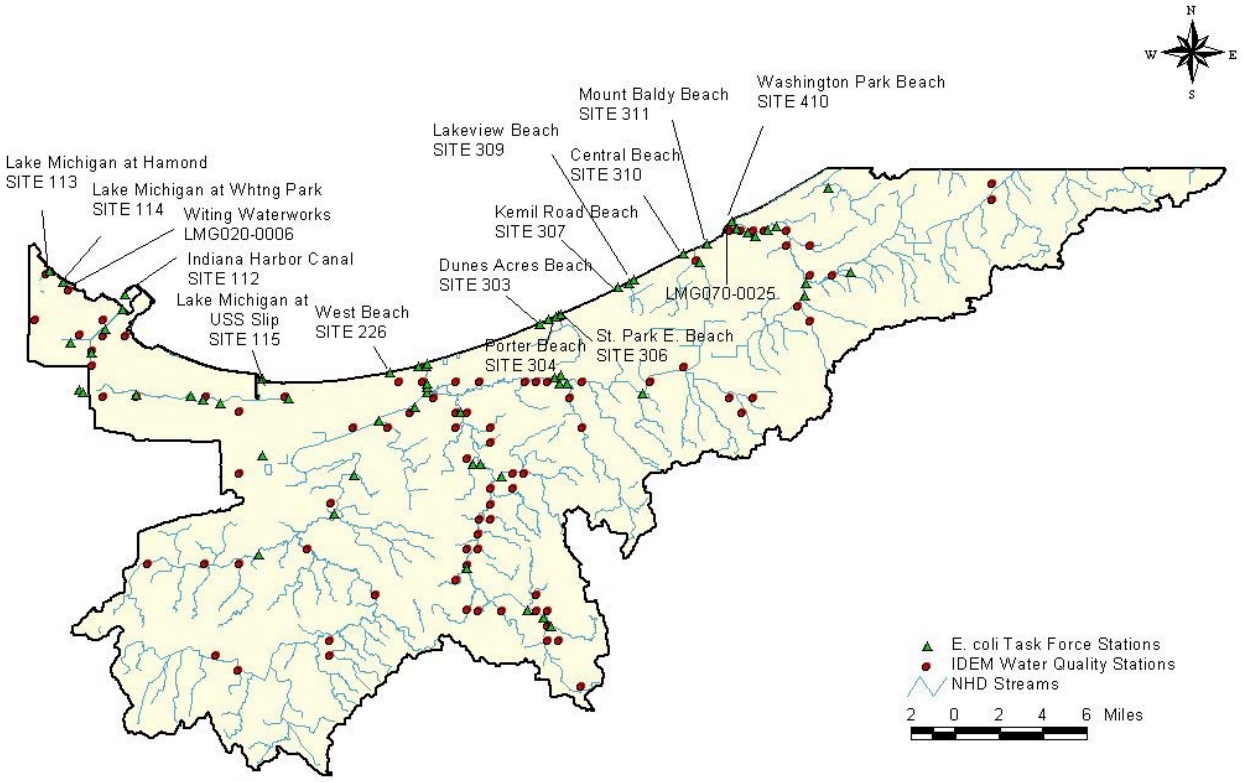

Figure 9. Location of IDEM and *E. Coli* Task Force surface water quality monitoring stations.

5.1 Adherence to QA/QC

Development of a TMDL requires that rigorous data screening procedures be conducted to ensure the accuracy of the information used to determine existing loads and, ultimately, the necessary load reductions. IDEM has established the following guidelines for determining the acceptability of data:

- The data have been collected and analyzed using QA/QC procedures contained in the State's QA/QC plan entitled "Quality Assurance Project Plan for Indiana Surface Water Quality Monitoring Programs;" or

- The data have been collected and analyzed using QA/QC procedures other than those contained in the State's QA/QC plan that are:

    i. comparable to the QA/QC procedures contained in the State's QA/QC plan; and
    ii. approved, in writing, by the State; or

- The data have otherwise been validated and accepted by the State.

The IDEM water quality data described in this section of the Data Report meet the first guideline because the data were collected by IDEM in accordance with the "Quality Assurance Project Plan for Indiana Surface Water Quality Monitoring Programs". The QA/QC procedures used by members of the *E. Coli* Task Force are still being reviewed to determine if they are comparable to the state's plan.

5.2 Confirmation of Impairment and its Extent

Under the Clean Water Act, every state must adopt water quality standards to protect, maintain, and improve the quality of the nation's surface waters. These standards represent a level of water quality that will support the Clean Water Act's goal of "swimmable/fishable" waters. Water quality standards consist of three different components:

- **Designated uses** reflect how the water can potentially be used by humans and how well it supports a biological community. Examples of designated uses include aquatic life support, drinking water supply, and recreation. Every water in Indiana has a designated use or uses; however, not all uses apply to all waters.
- Criteria express the condition of the water that is necessary to support the designated uses. **Numeric criteria** represent the concentration of a pollutant that can be in the water and still protect the designated use of the waterbody. **Narrative criteria** are the general water quality criteria that apply to all surface waters. These criteria state that all waters must be free from sludge; floating debris; oil and scum; color- and odor-producing materials; substances that are harmful to human, animal or aquatic life; and nutrients in concentrations that may cause algal blooms
- The **antidegradation policy** establishes situations under which the state may allow new or increased discharges of pollutants, and requires those seeking to discharge additional pollutants to demonstrate an important social or economic need. This policy only applies to surface water within the Great Lakes system.

Most water bodies in Indiana are designated for recreational use. The numeric criteria associated with protecting the recreational use are described below.

> "This subsection establishes bacteriological quality for recreational uses. In addition to subsection (a), the criteria in this subsection are to be used to evaluate waters for full body contact recreational uses, to establish wastewater treatment requirements, and to establish effluent limits during the recreational season, which is defined as the months of April through October, inclusive. *E. Coli* bacteria, using membrane filter (MF) count, shall not exceed one hundred twenty-five (125) per one hundred (100) milliliters as a geometric mean based on not less than five (5) samples equally spaced over a thirty (30) day period nor exceed two hundred thirty-five (235) per one hundred (100) milliliters in any one (1) sample in a thirty (30) day period." [Source: Indiana Administrative Code Title 327 Water Pollution Control Board. Last Updated October 1, 2002]

Indiana's portion of Lake Michigan has been listed as impaired for violations of the *E. Coli* criteria. The sections below discuss the nature of this impairment.

5.2.1 Comparison to Geometric Mean Standard

The geometric mean portion of the Indiana *E. Coli* standard requires that five samples be collected during a 30-day period. *E. Coli* was generally sampled weekly along the Lake Michigan shoreline during the recreation season to evaluate this standard. Since 1984, 31 of the 38 shoreline monitoring stations had sufficient *E. Coli* samples to meet the 30-day criteria. Among those sites, there were 3,995 unique 30-day periods where geometric means were calculated. For the purpose of this report, a unique 30-day period is defined as any 30-day period at a specific station during the recreation season that had at least five *E. Coli* samples. Because of this interpretation, weekly sampling at stations created instances where each new weekly sample created a new 30-day period and a new calculated geometric mean. Therefore some *E. Coli* concentrations were used in more than one 30-day geometric mean calculation. Out of the 3,995 unique 30-day periods, 942 periods (24 percent) had five or more samples with geometric means greater than 125 coliforms per 100 milliliters. All but seven stations (77 percent) had geometric means exceeding the standard (Figure 10). Stations 301 (Derby Ditch), 302 (Dunes Creek), 308 (Kintzele Ditch), and 407 (Trail Creek) had the largest percentage of geometric means exceeding the standard (greater than 90 percent at each station).

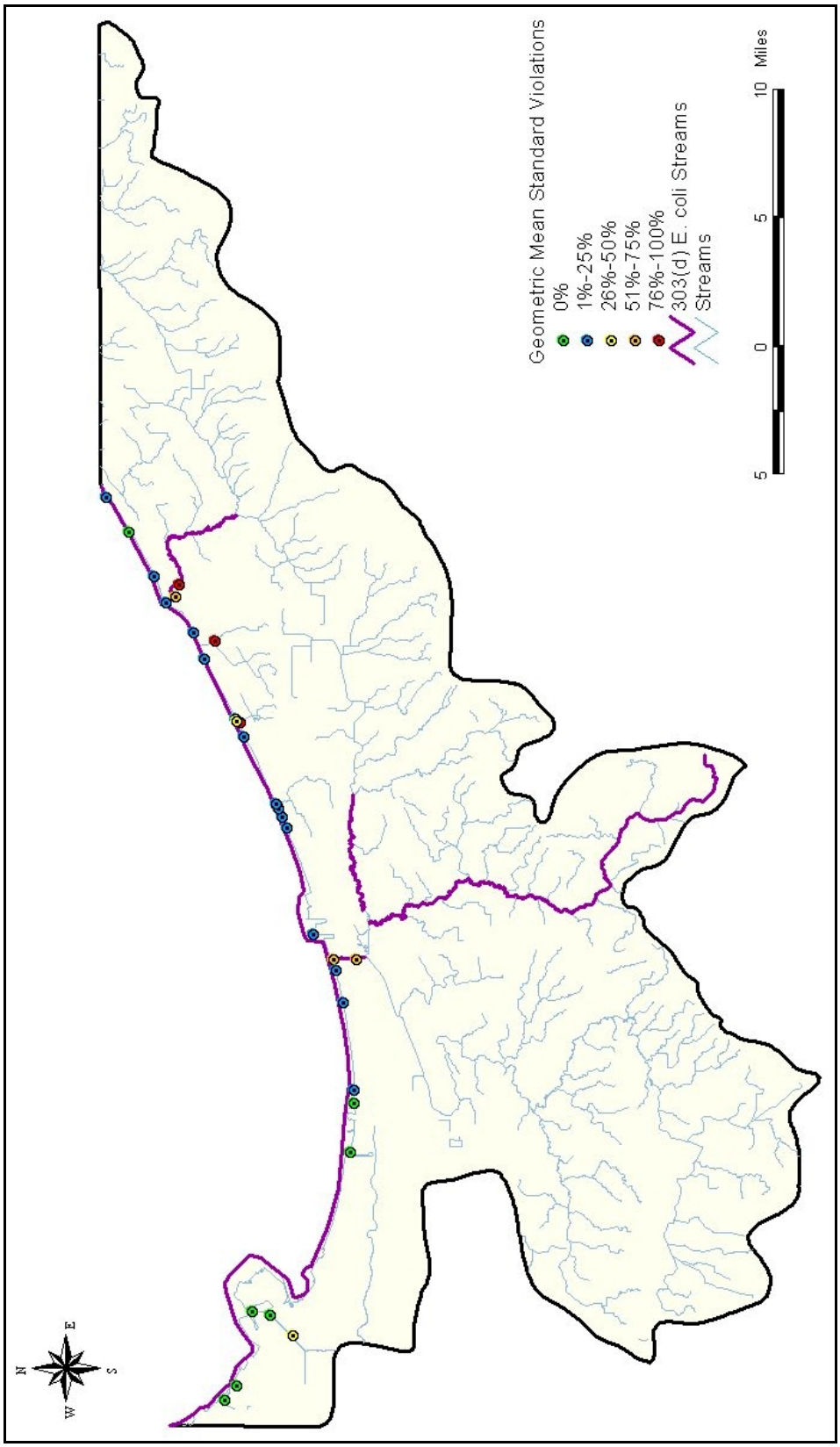

Figure 10. Geometric mean violations for shoreline stations

5.2.2 Comparison to the Never Exceed Standard

The never exceed standard applies to all grab samples collected during the recreational season. Figure 11 presents the spatial distribution of violations to the standard at the shoreline stations. Thirty-two of the thirty-eight shoreline monitoring stations (84 percent) had at least one observation that exceeded 235 coliforms per 100 mL. Stations 301(Derby Ditch), 302(Dunes Creek), and 407(Trail Creek) had the largest percentage of samples exceeding the standard (over 60 percent at each station). Of all the *E. Coli* samples collected at shoreline stations, 14 percent of the samples exceeded the standard.

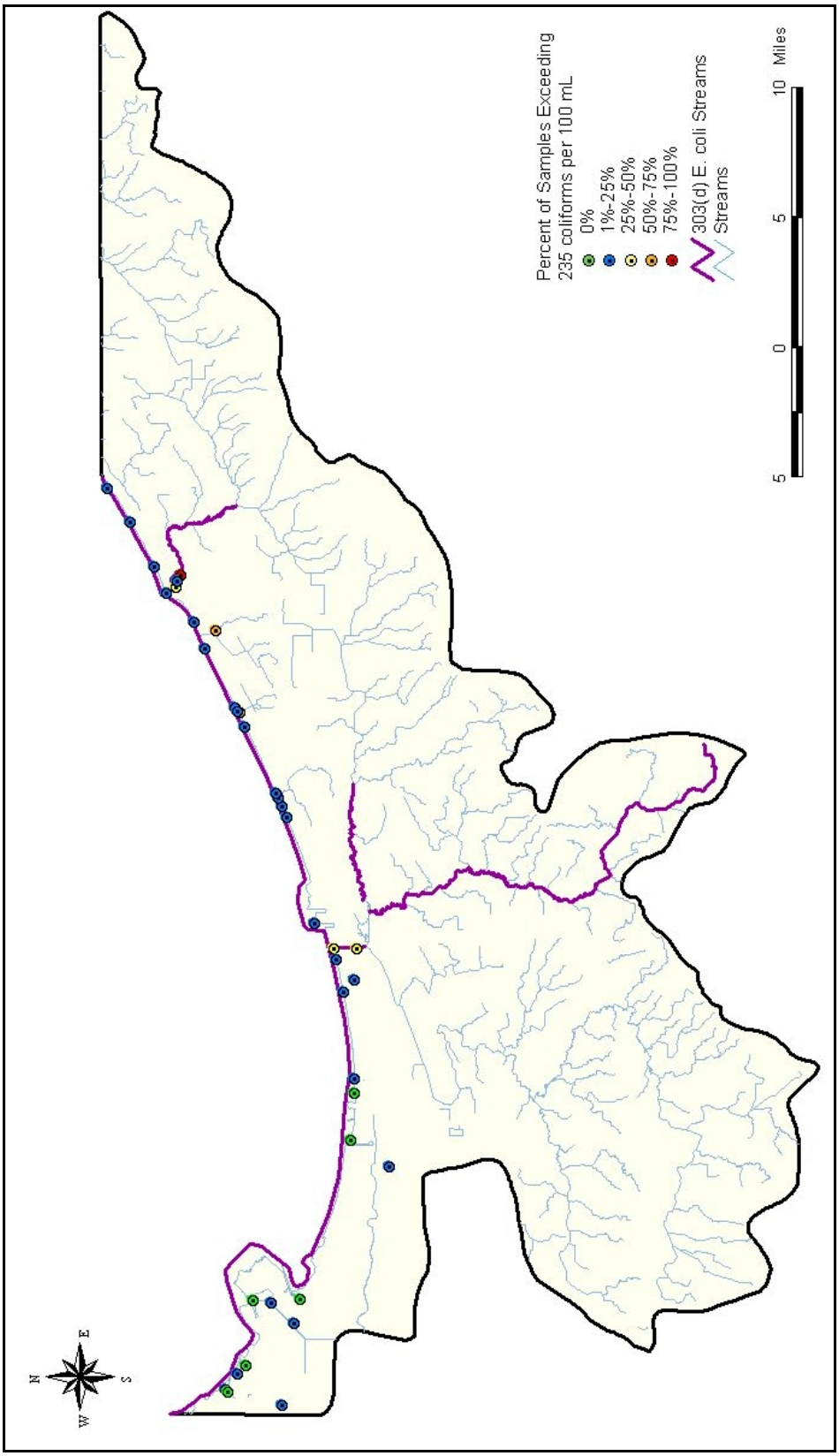

Figure 11. Never-exceed standard violations for shoreline stations

5.3 Comparison of *E. Coli* Data To Other Relevant Parameters

Many factors can influence the survival of *E. Coli* bacteria in the environment. These factors include water temperature, solar radiation, pH and settling out of bacterial particles and aggregates. The section below discusses the influence of each of these factors for the three stations with the most *E. Coli* data. These findings will be incorporated into the modeling analysis. For example, it will be important for the model to accurately simulate those parameters that are found to be highly correlated with *E. Coli*.

5.3.1 Temperature

Temperature has an inverse relationship with the survival of *E. Coli*, with survival typically decreasing as water temperature increases. Water temperature is considered the single most important modifier of pathogen decay rates in fresh water (USEPA, 2001).

Figures 12 through 14 show the relationship between temperature and *E. Coli* at three representative stations along the Lake Michigan shoreline in Indiana: station 226 at West Beach, station 307 at Kemil Road Beach, and station 311 at Mount Baldy Beach. There is not a strong correlation at any of the stations. However, there does appear to be a weak increasing trend in *E. Coli* with temperature at all three stations. Higher *E. Coli* concentrations were generally found within the 20°C to 28°C temperature range. This range also corresponds to the warmer months in the year.

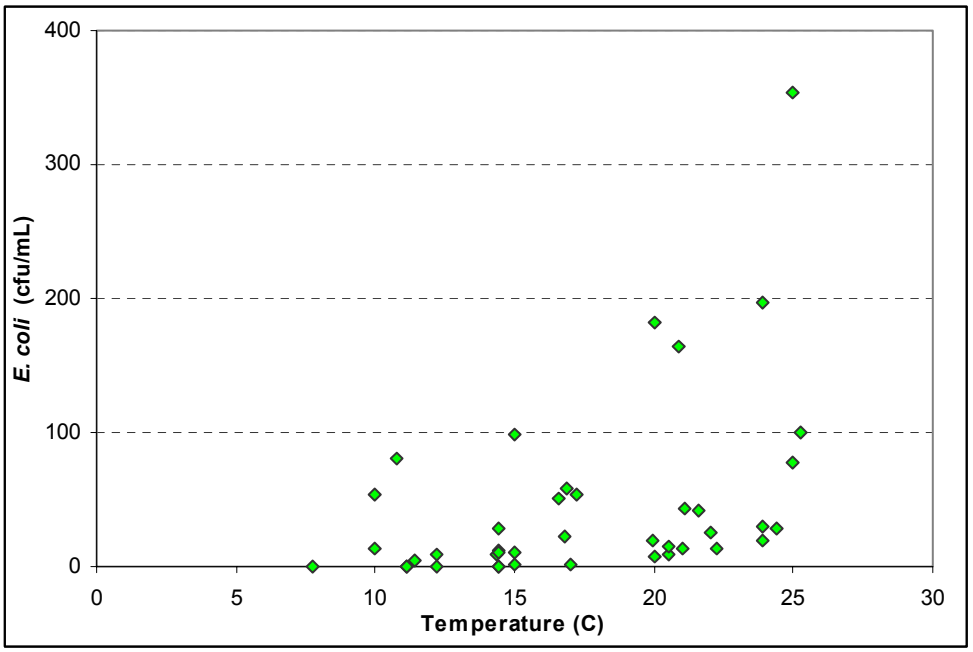

Figure 12. Correlation between *E. Coli* and temperature at station 226 (West Beach).

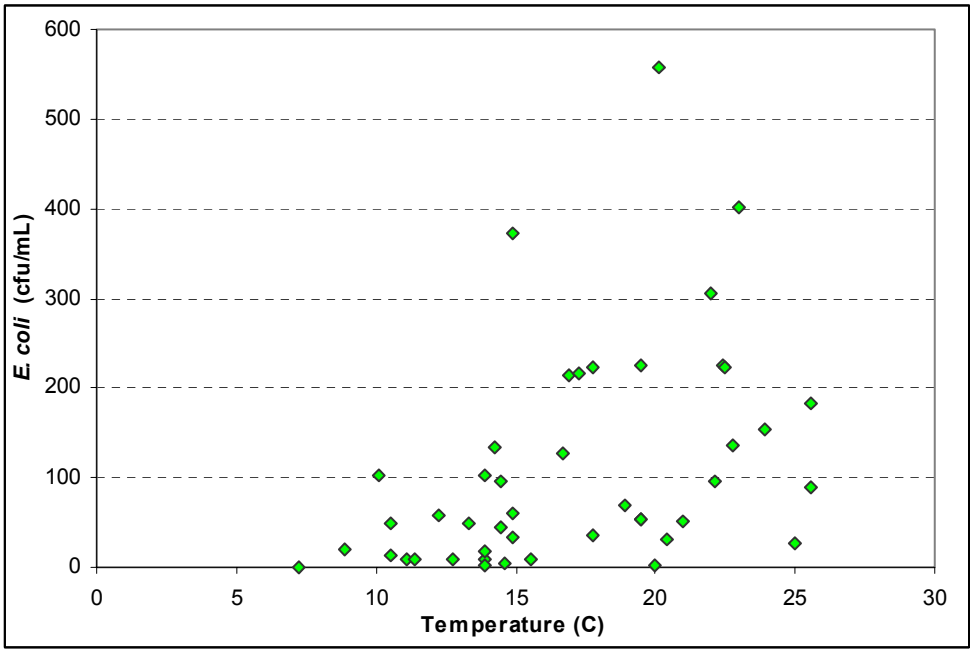

Figure 13. Correlation between *E. Coli* and temperature at station 307 (Kemil Road Beach).

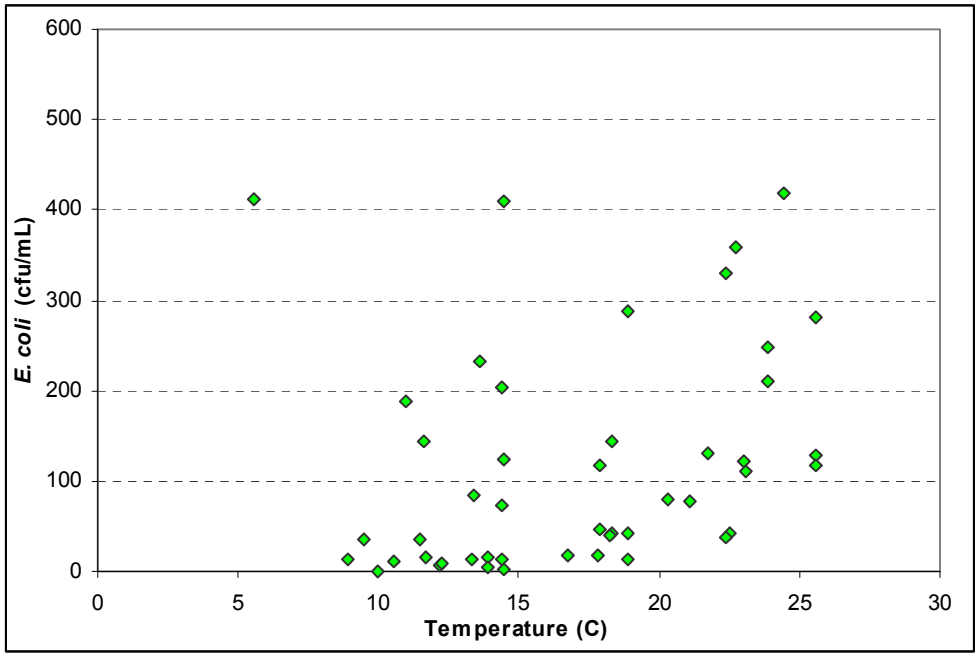

Figure 14. Correlation between *E. Coli* and temperature at station 311 (Mt. Baldy Beach).

5.3.2 Sediment

Many studies have shown that there are often much higher numbers of indicator bacteria in sediments than in overlaying waters. Bacterial cells settle from the water column as discrete entities as well as larger aggregates of fecal material. Once settled, pathogens have an increased survival time in the sediments due to protection from sunlight and temperature.

To examine this issue, *E. Coli* concentrations were plotted along with the corresponding total suspended solids (TSS) concentrations. Figure 15 shows a weak correlation between TSS and *E. Coli* at station LMG020-0008, which is located near the Northwest Indiana Water Company, Ogden Dunes Treatment Plant. Few TSS samples were available for other shoreline stations, and no other sediment data (e.g., turbidity, Secchi depth) were available.

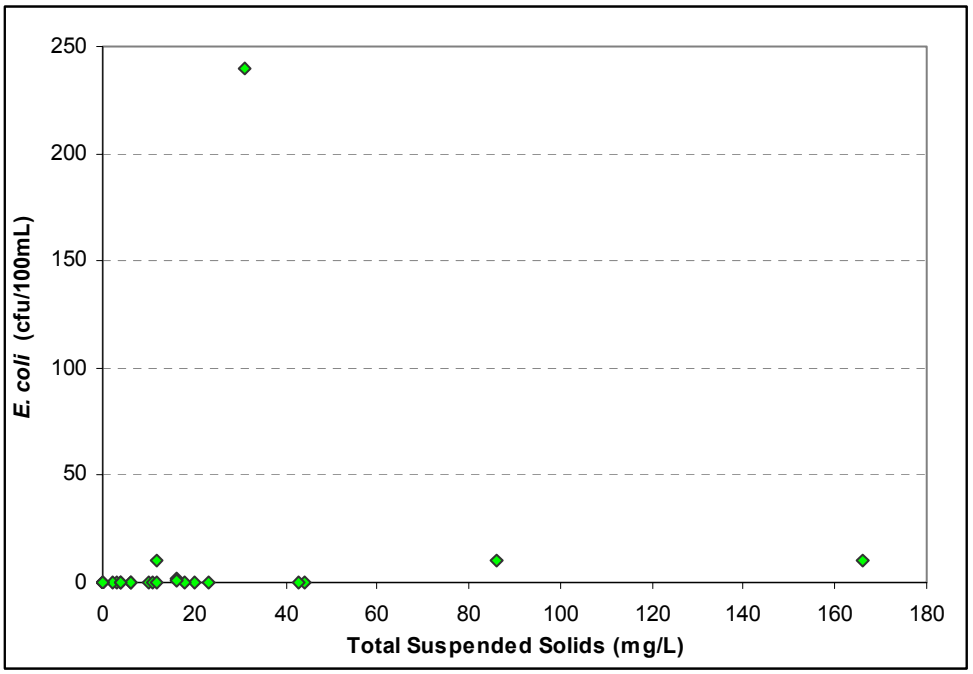

Figure 15. Relationship between *E. Coli* and TSS at station LMG020-0008 (East Chicago Waterworks).

5.3.3 pH

pH is a measure of the acidity of the water. It is measured on a scale from 0 (most acidic) to 14 (most alkaline), with 7 considered neutral. pH affects many chemical and biological processes in the water, such as the availability and toxicity of nutrients, metals, and other important compounds. Different organisms have different ranges of pH within which they flourish. Most aquatic organisms prefer a range of 6.5 to 8.0 Changes in acidity can be caused by atmospheric deposition (acid rain), surrounding rock, and wastewater discharges.

Figures 16 through 18 show that there is not a strong correlation between *E. Coli* and pH for the available data.

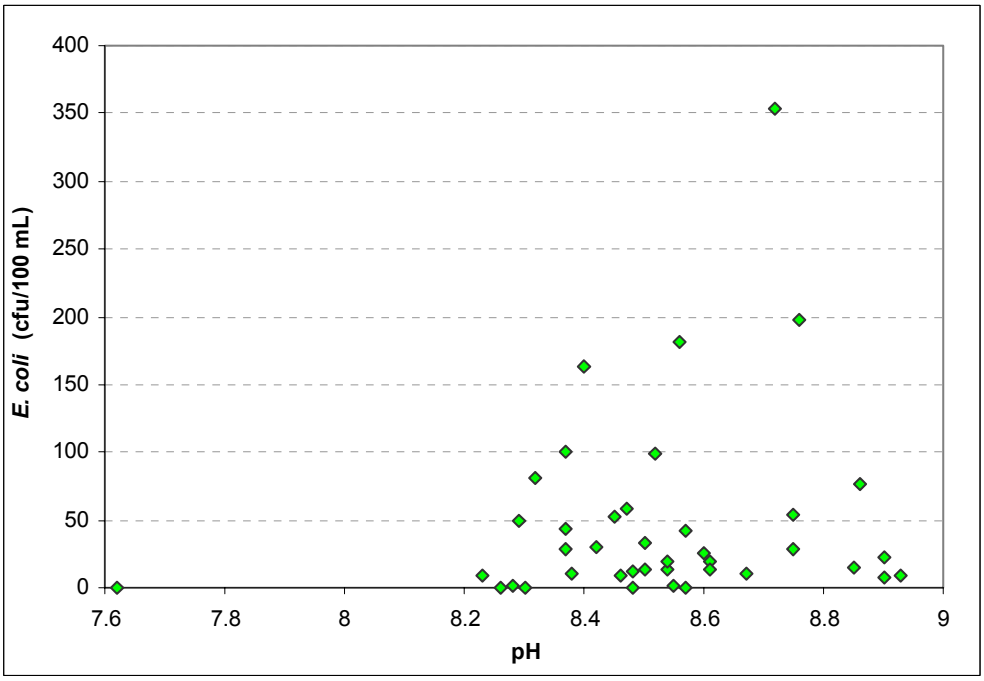

Figure 16. Relationship between pH and *E. Coli* at station 226 (West Beach).

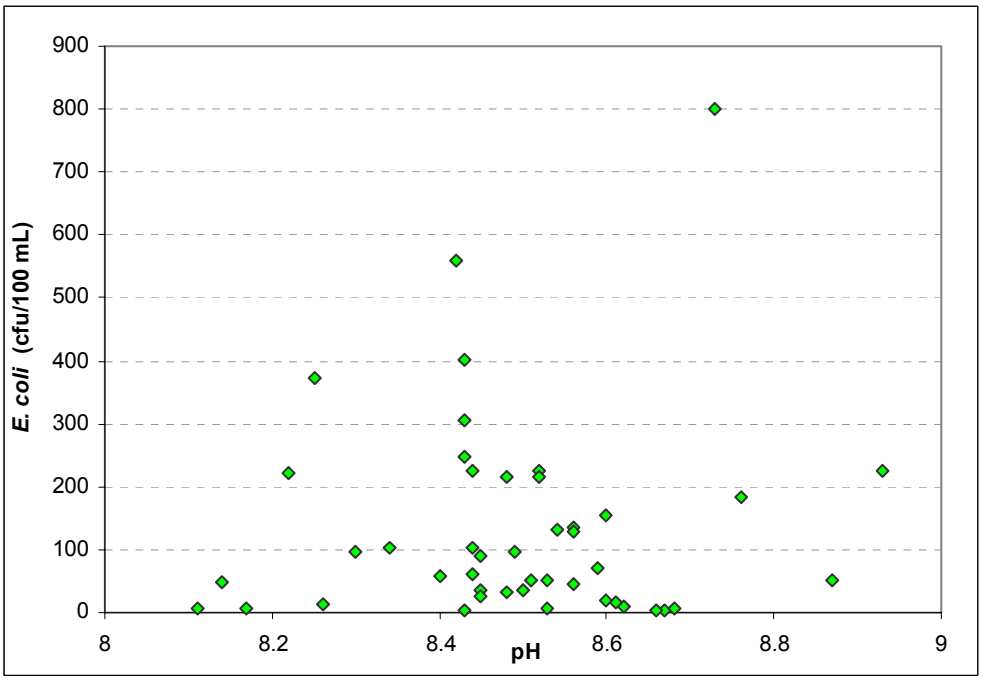

Figure 17. Relationship between pH and *E. Coli* at station 307 (Kemil Road Beach).

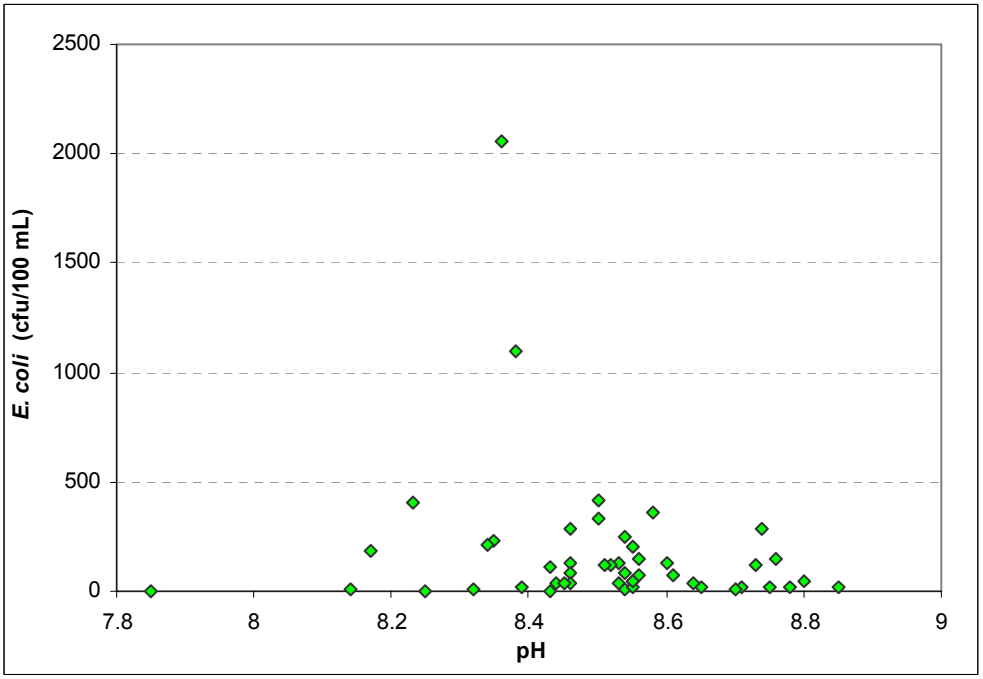

Figure 18. Relationship between pH and *E. Coli* at station 311 (Mt. Baldy Beach).

5.3.4 Time of Day

Sunlight intensity is inversely related to the survival of *E. Coli*. *E. Coli* concentrations generally decrease with more sunlight intensity and ultraviolet rays. With respect to time, this relationship suggests that *E. Coli* concentrations in a waterbody should decrease from sunrise to sunset throughout a particular day. Because samples were generally only sampled once per day at a station, various sampling times from different days were compared. Figures 19 through 21 show time of day versus *E. Coli* at three stations along the Lake Michigan shoreline. There was no apparent relationship at any of the stations. Note, however, that no observations were made after 2:00 pm.

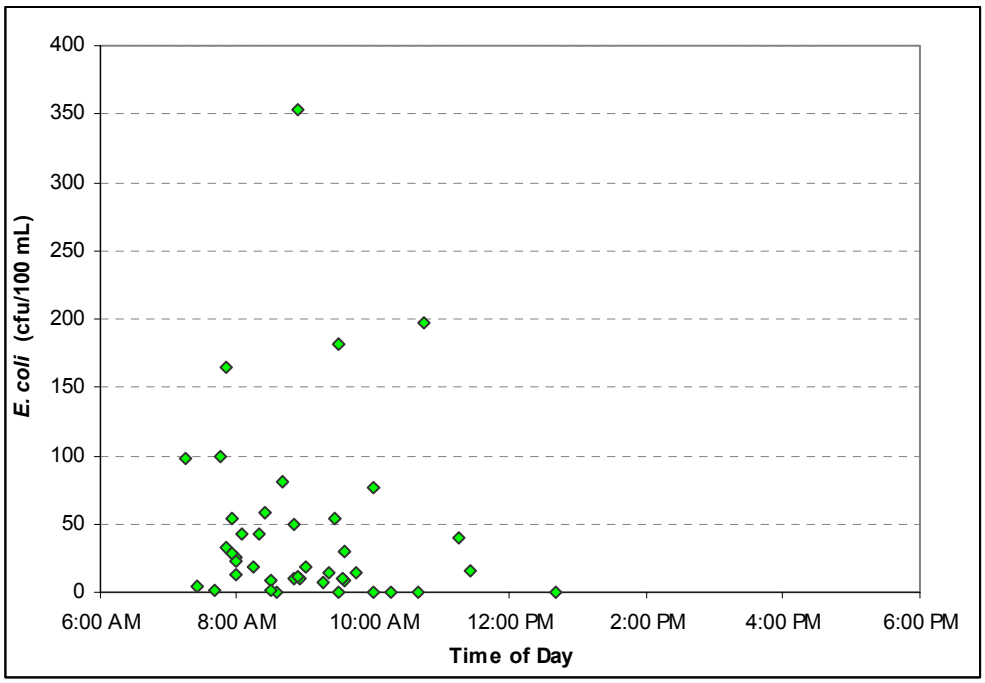

Figure 19. Relationship between *E. Coli* and time at station 226 (West Beach).

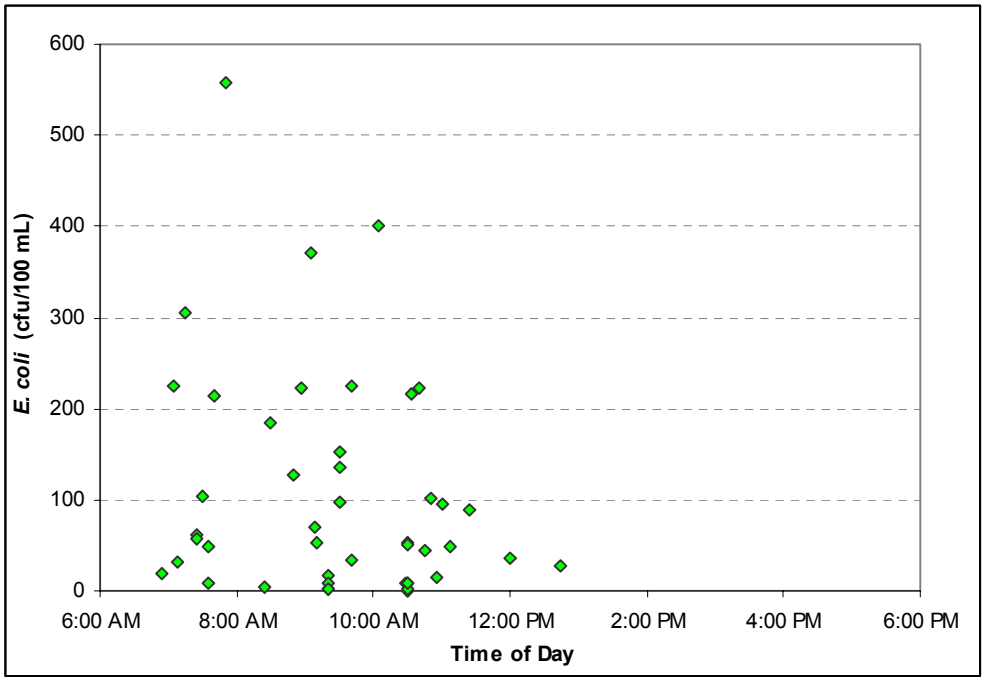

Figure 20. Relationship between *E. Coli* and time at station 307 (Kemil Road Beach).

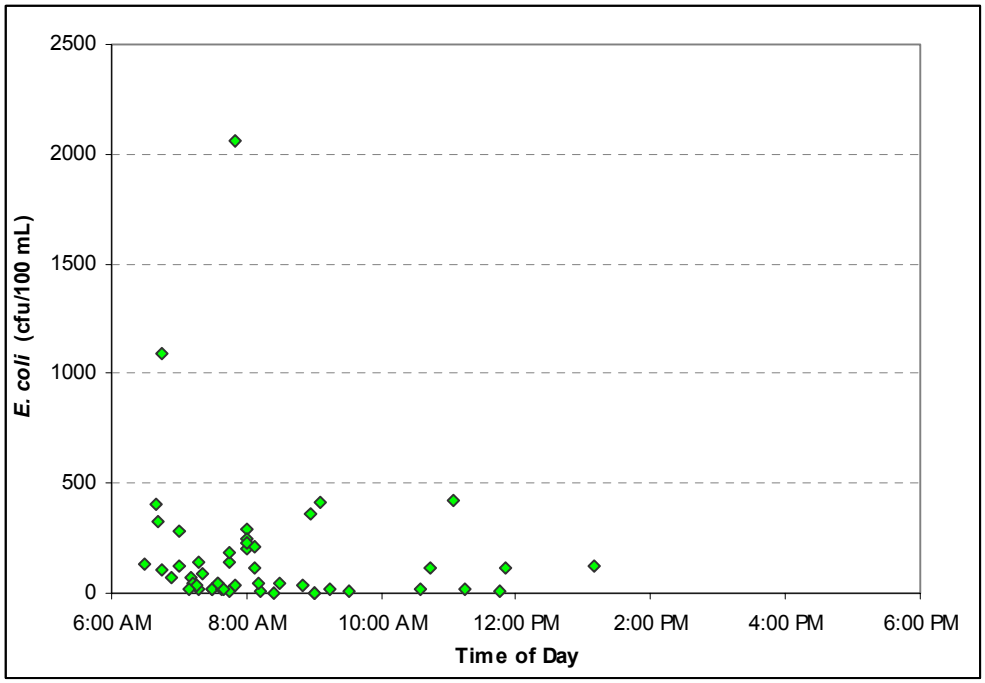

Figure 21. Relationship between *E. Coli* and time at station 311 (Mt. Baldy Beach).

5.3.5 Seasonal Variation

The distribution of *E. Coli* concentrations over a specific year can provide hints about sources and the survival dynamics of the bacteria. Figures 22 through 24 present concentrations versus month for the year 2001. Peak concentrations are noted during the summer and early fall in all three stations. Low concentrations are noted in early spring. This variation may be tied to variations in temperature over the year.

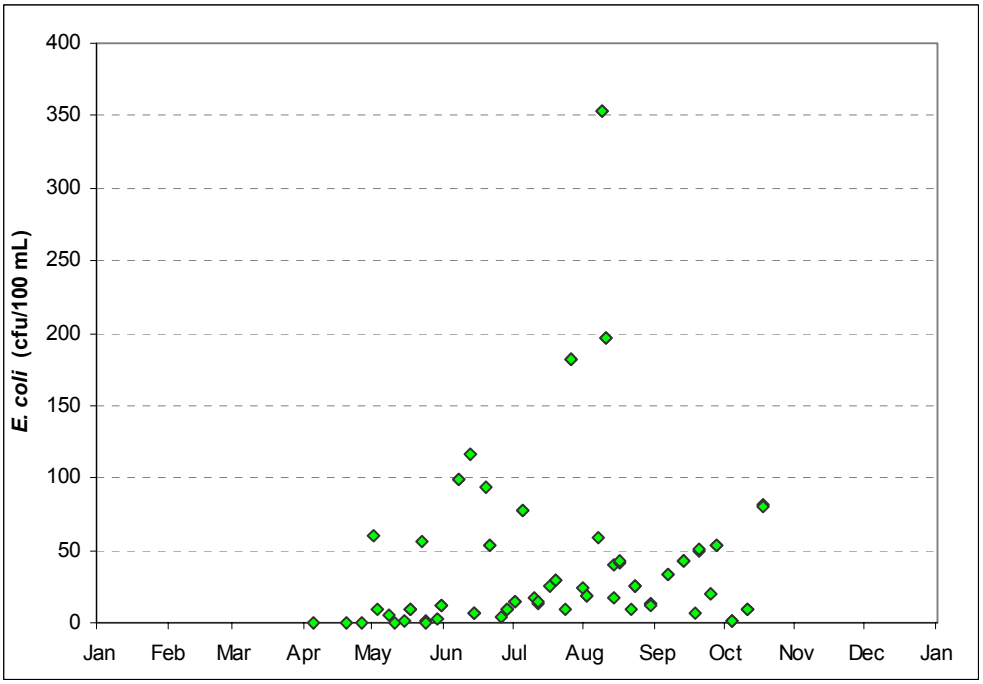

Figure 22. 2001 *E. Coli* data at station 226 (West Beach).

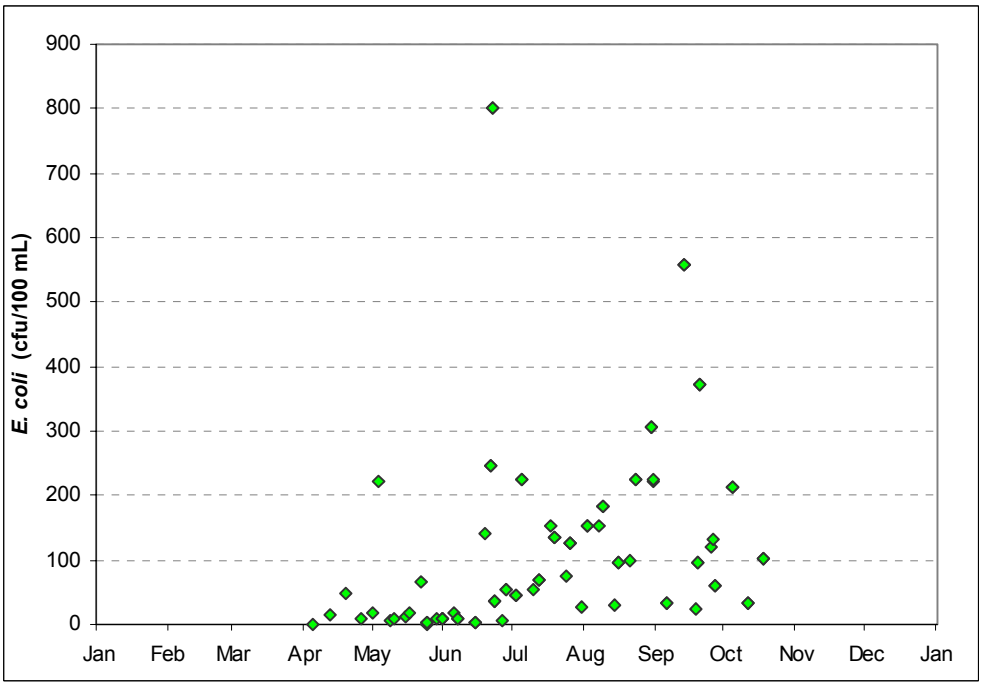

Figure 23. 2001 *E. Coli* data at station 307 (Kemil Road Beach).

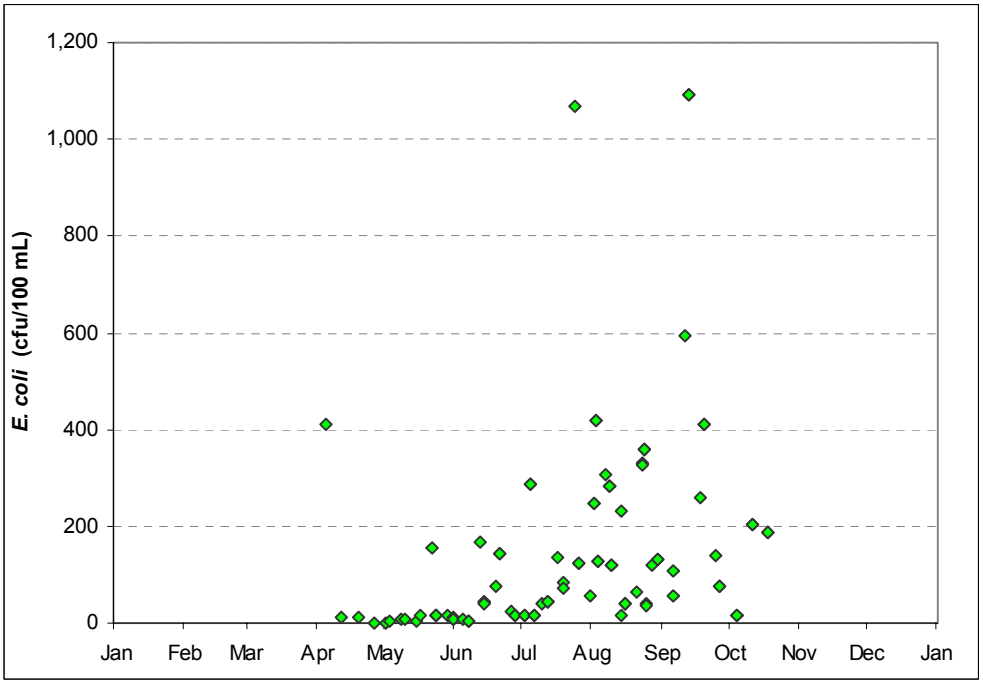

Figure 24. 2001 *E. Coli* data at station 311 (Mt. Baldy Beach).

6.0 EVALUATION OF DATA FOR TMDL DEVELOPMENT

The first step in the TMDL development process is to gather and assess all available data relevant to the watershed and the receiving water. The required data can be broken into two general types: point data and spatial data. The point data include water quality monitoring and discharge measurements, as well as basic meteorological data required by watershed and water quality models. Acquisition and processing of spatial or geographic data requires a fundamentally different approach from point data. Key spatial coverages for the Lake Michigan watershed include land use/land cover, stream network, soils, and lake bathymetry.

This report describes the progress that has been made to date in collecting and analyzing the available data for the Lake Michigan shoreline. Additional data have been requested from various organizations within the watershed. Based upon a review of the currently available data and those data that are expected to be received, sufficient information appears to exist to develop the TMDL. A more conclusive determination will be made following the site visit and review of additional data on *E. Coli* sources and lake circulation patterns.

Table 6. Summary of data needed for development of TMDL.

Data Type	Data	Source(s)	Available	Acceptable
Point Data	Stream flow	USGS	U	Yes
	Surface and ground water quality monitoring data	IDEM *E. Coli* Taskforce	U U	Yes Unknown
	Meteorological data within and in close proximity to the watershed	NCDC	U	Yes
	Discharge monitoring records from existing permitted facilities	IDEM	U	Yes
Spatial Data	Land Use/Land Cover	MRLC	U	Yes
	Lake Bathymetry	NOAA	U	Yes
	Topography	Digital Elevation Model	U	Yes
	Circulation patterns within the lake	NOAA Army Corp of Engineers	° °	Unknown Unknown
	Location of areas with failing/illicitly connected septic systems	County Health Departments	°	Unknown
	Information on other sources of *E. Coli*	Various agencies	°	Unknown
	Digital Orthoquads	USGS	U	Yes

U = Obtained by Tetra Tech. ° = Not yet received.

7.0 REFERENCES

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APPENDIX A—SUMMARY OF THE PERIOD OF RECORD AND SAMPLING FREQUENCY AND RELEVANT STATISTICS FOR *E. COLI* MONITORING, SHORELINE STATIONS

Station ID	Site	Description	Count	Period of Record		Observed *E. Coli* (cfu/100ml)		
				From	To	Average	Min	Max
1001	Lake Street Beach	Lakestreet Beach	187	May-84	Sep-01	52	1	2,100
1002	Marquette Park Beach	Marquette Park Beach	17	May-01	Sep-01	30	2	173
110	Indiana Harbor Canal	IHSC at Dickey Rd	91	Apr-98	Oct-00	50	0	40,000
111	Indiana Harbor Canal	IHSC at Mouth	91	Apr-98	Oct-00	5	0	900
112	Indiana Harbor Canal	NE Corner Indiana Harbor	91	Apr-98	Oct-00	4	0	80
113	Lake Michigan	Lake Mich at Hamd Mra	91	Apr-98	Oct-00	9	0	1,000
114	Lake Michigan	Lake Mich at Whtng Park	91	Apr-98	Oct-00	7	0	1,200
115	Lake Michigan	Lake Mich at USS Slip	91	Apr-98	Oct-00	2	0	24
223	Burns Ditch	Burns Waterway at US 12	134	Apr-98	Oct-01	148	0	20,700
225	Burns Ditch	Burns Harbor At Mouth	113	Apr-98	Oct-01	128	0	18,800
226	West Beach	West Beach	350	May-84	Jul-02	30	0	5,000
227	Ogden Dunes Beach	Ogden Dunes Beach	340	May-84	Jul-02	28	0	40,000
228	Lake Michigan	L. Mich at Port of Indiana	91	Apr-98	Oct-00	30	0	880
301	Derby Ditch	Derby Ditch at Mouth	172	Apr-98	Jul-02	487	0	40,000
302	Dunes Creek	Dunes Creek at Mouth	173	Apr-98	Jul-02	505	0	40,000
303	Dune Acres Beach	Dune Acres Beach	176	Apr-98	Jul-02	24	0	358
304	Porter Beach	Porter Beach	349	May-84	Jul-02	26	0	941
305	St Park West Beach	St.Park W Beach	339	Jul-84	Jul-02	80	0	40,000
306	St Park East Beach	StPark E Beach	284	May-89	Jul-02	73	0	2,068
307	Kemil Road Beach	Kemil Road Beach	354	May-84	Jul-02	25	0	800
308	Kintzele Ditch	Kintzele Ditch at Mouth	155	Apr-98	Jul-02	348	0	40,000
309	Lakeview Beach	Lakeview Beach	354	May-84	Jul-02	40	0	40,000
310	Central Beach	Central Beach	355	May-84	Jul-02	40	0	40,000
311	Mount Baldy Beach	Mt. Baldy	362	May-84	Jul-02	47	0	40,000
313	Dunbar Beach	Dunbar	187	Apr-98	Jul-02	62	0	716
407	Trail Creek	Trail Creek at East St.	27	May-01	Oct-01	500	110	8,300
408	Trail Creek	Trail Crk at Franklin St.	118	Apr-98	Oct-01	185	10	16,600
410	Washington Park Beach	Washington	296	May-84	Sep-01	54	0	966
413	California Avenue Beach	California Avenue Beach	129	Apr-98	Sep-01	38	0	418
414	Long Beach	Long Beach Stop 24	128	Apr-98	Sep-01	16	0	411
416	Michiana Shores Beach	Michiana Shrs Bea. Stop 37	128	Apr-98	Sep-01	15	0	40,000
LMG020-0006	Lake Michigan	Raw Water, Whiting Waterworks	75	Jan-91	Mar-98	10	0	300

Station ID	Site	Description	Count	Period of Record		Observed *E. Coli* (cfu/100ml)		
				From	To	Average	Min	Max
LMG020-0008	Lake Michigan	Raw Water, E Chicago Waterworks	88	Jan-90	Nov-00	10	0	2,400
LMG020-0009	Lake Michigan	Raw Water, Northwest Indiana Water Company (Gary), Borman Pk Treatment Plant	97	Jan-90	Nov-00	480	0	4,000
LMG020-0010	Lake Michigan	Raw Water, Hammond Waterworks	84	May-90	Mar-98	30	0	960
LMG020-0013	Lake Michigan	Raw Water, Northwest Indiana Water Company, Ogden Dunes Treatment Plant	33	Feb-97	Nov-00	15	0	1,100
LMG020-0014	Wolf Lake	Culvert at State Line Rd at End of 129th St in Hammond	64	Mar-91	Mar-98	25	0	900
LMG070-0004	Lake Michigan	Raw Water, Michigan City Waterworks	91	Jan-90	Dec-00	25	0	2,000

APPENDIX B—SUMMARY OF THE PERIOD OF RECORD AND SAMPLING FREQUENCY AND RELEVANT STATISTICS FOR *E. COLI* MONITORING, ALL OTHER STATIONS

Station ID	Stream	Description	Count	Period of Record		Observed *E. Coli* (cfu/100ml)		
				From	To	Average	Min	Max
409	Trail Creek	Trail Crk Mich. City Harbor	91	Apr-98	Oct-00	63	0	40,000
412	White Ditch	White Ditch	91	Apr-98	Oct-00	258	0	10,000
415	Shoreland Hills Beach	Shoreland Hills Bea. Stop 31	128	Apr-98	Sep-01	16	0	365
Dunes1	Brown Ditch	Brown	43	Apr-01	Jul-02	827	98	4,993
LMG020-0001	Grand Calumet River	at US Steel	7	Oct-99	Nov-00	3	0	390
LMG020-0003	Indiana Harbor Canal	Bridge on Dickey Rd, E Chicago	57	Jan-90	Nov-99	90	0	3,400
LMG020-0004	Indiana Harbor Canal	Bridge on Columbus Dr, E Chicago	83	Jan-90	Nov-99	260	0	84,000
LMG020-0005	Indiana Harbor Canal	Bridge on Indianapolis Blvd, E Chicago	85	Jan-90	Nov-99	50	0	1,700
LMG020-0011	Grand Calumet River	Bridge on Kennedy Ave, E Chicago	86	Jan-90	Sep-00	165	0	45,000
LMG020-0012	Grand Calumet River	Bridge St Bridge Near US Steel, Gary	101	Jan-90	Nov-00	40	0	160,000
LMG020-0016	Indiana Harbor Canal	Bridge on SR 312, Park on side street, E of Water Tower	5	Jul-00	Aug-00	24	10	687
LMG030-0006	Turkey Creek	N of New Elliot, Pull Over on W Side of St, Narrow Bridge	5	Jul-00	Aug-00	178	29	2,419
LMG030-0007	Turkey Creek	SR 53 Broadway, S of 61st St	5	Jul-00	Aug-00	1,046	517	1,986
LMG030-0008	Deep River	D/s of dam in Festival Park and Lake George, u/s of gage, Hobart	5	Jul-00	Aug-00	30	10	129
LMG030-0009	Deep River	Deep River County Park, Ped Bridge	4	Jul-00	Aug-00	448	345	160,000
LMG030-0010	Deep River	Grand Blvd bridge, South of US 30, 2 miles	5	Jul-00	Aug-00	770	411	2,419
LMG030-0011	Deep River	61st Ave, W SR 51, South of Hobart	5	Jul-00	Aug-00	387	261	921
LMG040-0003	Burns Ditch	Portage Boat Yard Dock, Portage	106	Jan-90	Nov-00	340	0	11,000
LMG040-0004	Little Calumet	SR 53 bridge, S of Exit 10 I-80	5	Jul-00	Aug-00	108	10	1,414
LMG040-0005	Burns Ditch	SR 51 bridge, north of I-94, Exit 15	5	Jul-00	Aug-00	387	201	160,000
LMG050-0006	Salt Creek	US 20 Bridge, Portage	97	Jan-91	Nov-00	460	0	7,100
LMG050-0007	Salt Creek	SR 130 Bridge, Below STP, Near Valparaiso	94	Jan-91	Nov-00	500	0	8,800

Station ID	Stream	Description	Count	Period of Record		Observed *E. Coli* (cfu/100ml)		
				From	To	Average	Min	Max
LMG050-0009	Salt Creek	500 N Bridge, E of 450 W, N of SR130	5	Jul-00	Aug-00	921	387	1,553
LMG050-0011	Salt Creek	First road access point after spring fed wetland - Sager Rd & approx. CR 150 S	4	Oct-00	Oct-00	285	200	380
LMG050-0012	Salt Creek	SR 2 & Salt Creek	5	Sep-00	Oct-00	400	160	850
LMG050-0013	Salt Creek	Sagers Lake Outlet & Meridian Rd	5	Sep-00	Oct-00	150	100	500
LMG050-0014	Salt Creek	Access from 1st East-West road north of US Route 30	5	Sep-00	Oct-00	250	80	1,600
LMG050-0015	Salt Creek	Valparaiso WWTP	5	Sep-00	Oct-00	10	0	60
LMG050-0016	Salt Creek	Joliet Road & Salt Creek	5	Sep-00	Oct-00	50	30	160,000
LMG050-0017	Beauty Cr	SR 130 & Beauty Creek	5	Sep-00	Oct-00	60	20	170
LMG050-0018	Unnamed Trib	Unnamed Tributary & CR 250 W	5	Sep-00	Oct-00	460	190	3,000
LMG050-0019	Clark Ditch	Clark Ditch & Clark Ditch & Joliet Rd	5	Sep-00	Oct-00	560	320	1,100
LMG050-0020	Lake Louise Outfall	Stream downstream of Lake Louise & Joliet Rd	5	Sep-00	Oct-00	1,600	190	3,900
LMG050-0021	Unnamed Trib	Unnamed Tributary to Salt Creek at CR 400 N	5	Sep-00	Oct-00	150	90	1,300
LMG050-0022	Salt Creek	Salt Creek & SR 130, Fixed Station SLC-17	5	Sep-00	Oct-00	180	130	770
LMG050-0023	Pepper Cr	Pepper Creek & CR 325 W	5	Sep-00	Oct-00	120	40	280
LMG050-0024	Salt Creek	Salt Creek & 600 N	5	Sep-00	Oct-00	530	240	900
LMG050-0025	Trib of Salt Cr	CR 600 N, Trib of Salt Cr	5	Sep-00	Oct-00	300	90	990
LMG050-0027	Trib of Salt Cr	Salt Creek Tributary & SR 149	5	Sep-00	Oct-00	200	130	290
LMG050-0028	South Haven Sewer Works, Inc	South Haven Sewer Works, Inc. Effluent	5	Sep-00	Oct-00	10	0	100
LMG050-0029	Trib of Salt Cr	Salt Creek Tributary & CR 200 W	5	Sep-00	Oct-00	550	160	1,300
LMG050-0030	Salt Creek	Salt Creek & US HWY. 6 - Retired Fixed Station SLC-7	5	Sep-00	Oct-00	250	140	1,000
LMG050-0031	Damon Run	Damon Run & CR 200 W	5	Sep-00	Oct-00	1,000	240	1,900
LMG050-0034	Gustafson Ditch	Gustafson Ditch & SR 149	5	Sep-00	Oct-00	670	50	1,000
LMG050-0035	Trib of Salt Cr	Salt Creek Tributary & Portage Avenue(East of Portage)	5	Sep-00	Oct-00	60	20	200

Station ID	Stream	Description	Count	Period of Record		Observed *E. Coli* (cfu/100ml)		
				From	To	Average	Min	Max
LMG050-0036	Salt Creek	Salt Creek & CR 400 W, Retired USGS Gaging Station	5	Sep-00	Oct-00	370	200	1,000
LMG050-0037	Salt Creek	Salt Creek & US Hwy 20, Fixed Station SLC-1	5	Sep-00	Oct-00	480	100	12,000
LMG060-0005	Burns Ditch	SR 249 Bridge (Crisman R), Portage	110	Jan-90	Nov-00	130	0	5,500
LMG060-0006	Burns Ditch	Midwest Steel Catwalk, Portage - Outlet to Lake Michigan	5	Jul-00	Aug-00	150	30	430
LMG060-0007	Burns Ditch	Portage Public Marina, US Hwy 12	113	Jan-90	Nov-00	200	0	4,000
LMG060-0008	E Br Little Calumet River	SR 149, S of US Hwy 12, NW of Porter	108	Jun-90	Oct-00	305	0	9,700
LMG060-0009	E Br Little Calumet River	SaltCreek Landing,SR 249 Bridge, North of I-94 Exit 19	5	Jul-00	Aug-00	111	50	461
LMG060-0011	Little Calumet River	Bridge on CR 1300N, W of CR 450E	4	Jul-00	Aug-00	804	517	160,000
LMG060-0012	Burns Ditch	Upstream of Outlet to Lake Michigan - Midwest Steel Catwalk	5	Jul-00	Aug-00	80	40	900
LMG060-0013	E Br Little Calumet River	SR 249 & E Br of Little Calumet River	1	Aug-00	Aug-00	310	310	310
LMG060-0014	Samuelson Ditch	US 12 & Samuelson Ditch	5	Aug-00	Aug-00	10	0	330
LMG060-0015	E Br Little Calumet River	SR 149 - Fixed Station LCR 39 near Porter	5	Aug-00	Aug-00	400	120	920
LMG060-0016	E Br Little Calumet River	USGS Gaging Station near Porter on US 20	5	Aug-00	Aug-00	210	130	840
LMG060-0017	E Br Little Calumet River	Waverly Road & E Br Little Calumet River (Porter to Chesterton Area)	5	Aug-00	Aug-00	160	0	520
LMG060-0019	E Br Little Calumet River	E Br Little Calumet River & CR 250 E	5	Aug-00	Aug-00	250	100	820
LMG060-0020	E Br Little Calumet River	E Br Little Calumet River & CR 450 E	5	Aug-00	Aug-00	360	170	570
LMG060-0021	E Br Little Calumet River	E Br Little Calumet River & CR 600 E	5	Aug-00	Aug-00	270	200	1,100
LMG060-0022	E Br Little Calumet River	E Br Little Calumet River & Otis Rd - NW of Town of Otis	5	Aug-00	Aug-00	180	130	230
LMG060-0023	NE Trib	US 421 & Northeast Trib of E. Br. Little Calumet R.	5	Aug-00	Aug-00	120	0	200
LMG060-0024	SW Trib	US 421(Snyder Rd.) & Southwest Trib of E Br Little Calumet River	4	Aug-00	Aug-00	325	240	430
LMG060-0025	Coffee Creek	Morgan Ave bridge next to park	5	Jul-00	Aug-00	461	210	649

Station ID	Stream	Description	Count	Period of Record		Observed *E. Coli* (cfu/100ml)		
				From	To	Average	Min	Max
LMG070-0005	Trail Creek	Michigan City, Liberty St Bridge	98	Jan-91	Dec-00	345	0	160,000
LMG070-0007	Trail Creek	Sampled collected out from DNR station, next to I&M Power Plant	95	Jan-91	Oct-00	250	0	18,000
LMG070-0008	Trail Creek	US 12 Bridge, Michigan City	95	Jan-91	Dec-00	350	0	13,000
LMG070-0010	Trail Creek	Woziniak Rd, S of 400 N	5	Jul-00	Aug-00	186	141	921
LMG070-0011	Trail Creek	Old US 20 Bridge, S of US 20, E of Johnson Rd	5	Jul-00	Aug-00	866	260	160,000
LMG070-0012	Trail Creek	Fixed Station TC .5, Franklin St Bridge on US 421, Michigan City	5	Aug-00	Sep-00	90	20	380
LMG070-0013	Trail Creek	Fixed Station TC 1, US Highway 12 Bridge, Michigan City	5	Aug-00	Sep-00	90	40	360
LMG070-0014	Trail Creek	Michigan City WWTP Effluent	5	Aug-00	Sep-00	0	0	0
LMG070-0015	Trail Creek	Fixed Station TC 2, Liberty Bridge, Michigan City	5	Aug-00	Sep-00	520	290	610
LMG070-0016	Trail Creek	USGS Gaging Station, Springland Avenue	5	Aug-00	Sep-00	330	130	420
LMG070-0017	Trail Creek	US 35	10	Jul-00	Sep-00	391	30	160,000
LMG070-0018	Trail Creek	US 20	10	Jul-00	Sep-00	411	110	160,000
LMG070-0019	W Br of Trail Cr	W Br of Trail Creek, S of US 20 From Rd Leading to Orchard Highlands	5	Aug-00	Sep-00	500	30	3,100
LMG070-0020	E Br Trail Cr	E Br of Trail Creek at CR 600 W.	5	Aug-00	Sep-00	460	360	720
LMG100-0004	Galena River	Bridge on 125E, N of 900N	5	Jul-00	Aug-00	687	285	160,000